Chapter 1a Stock Assessment of Aleutian Islands Region Pollock

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Executive Summary

Development of a detailed age-structured stock assessment for the Aleutian Islands Region pollock began in 2003 (Barbeaux et al. 2003) and was further developed in 2004 and 2005 (Barbeaux et al. 2004, Barbeaux et al. 2005). In the initial study the near shore areas of the Aleutian chain island were isolated and identified as the Near, Rat, and Andreanof Island (NRA) sub-area. This sub-area was further refined to exclude the area east of 174°W to address data consistency issues. The Council supported this proposal and urged continuing development of an age-structured assessment model using data from the area west of 174°W (and omitting deep-water areas where survey data are unavailable).

Pollock fishery data collected near the eastern boundary of the Aleutian Islands region (between 174°W and 170°W) highlight stock structure uncertainty between the Aleutian Islands region, the Aleutian Islands Basin, and the EBS. Consequently, data from this area is excluded from all of the age-structured assessment models presented below. We do, however, recognize that fluctuations in biomass observed from the summer Aleutian Islands bottom trawl (AIBT) survey data from this area do not indicate clear cut patterns and that substantial uncertainty in the stock structure exists. We have included model configurations which include all of the AIBT survey data and one model that excludes data from the eastern NRA area (NRA area east of 174°W).

Spatial analyses of fishery, survey, and bycatch data using GIS methods reveal an important characteristic of pollock in the Aleutian Islands region: concentrations are highly variable and likely evolve quickly within seasons. These analyses underscore the challenge of evaluating stocks that: are highly mobile, spend variable time associated with the bottom, have patchy distributions, and are likely influenced by neighboring stocks.

Summary of major changes

The model configuration does not differ significantly from the models presented in the 2006 assessment. The only changes are that the pollock removals from 2006 and 2007 were added to the model and the age data from the 2006 Aleutian Islands bottom trawl survey were included in the model.

Changes in the assessment results

The maximum permissible ABC for 2008 and 2009 under Tier 3a are 28,160 t and 22,670 t, respectively. The OFL for 2008 and 2009 under Tier 3a are 34,040 t and 26,060 t respectively. The maximum permissible ABC under Tier 5 for both years using the lower natural mortality is 16,800 t and the OFL is 20,710 t.

Response to SSC 2006 Comments

The SSC commented that they supported continued research of the Aleutians pollock stock. To that end we completed the 2006 and 2007 Aleutian Islands Cooperative Acoustic Survey Study (AICASS) to ascertain whether it was possible to conduct acoustic surveys on pollock in the Central Aleutian Islands in the winter. This project was successful and provided not only verification of the technique, but valuable

data on the biology and health of the Aleutian Islands pollock stock. Some of the biological data such as age and length composition have been used directly in this assessment, other data such as pollock tissue samples await funding for further analysis. This project is being expanded in 2008 through NPRB funding with addition of diet and abundance studies on the local Steller sea lion population and inclusion of an additional acoustic survey in the area conducted by the R/V Oscar Dyson. This study will attempt to investigate the relationship between sea lion diet and abundance and possible prey fields observed during the standard and cooperative acoustic surveys.

Introduction

Walleye pollock (*Theragra chalcogramma*) are distributed throughout the Aleutian Islands with concentrations in areas and depths dependent on season. Generally, larger pollock occur in spawning aggregations during February – April. Three stocks of pollock inhabiting three regions in the Bering Sea – Aleutian Islands (BSAI) are identified in the U.S. portion of the BSAI for management purposes. These stocks are: the eastern Bering Sea pollock occupying the eastern Bering Sea shelf from Unimak Pass to the U.S.-Russia Convention line; the Aleutian Islands Region pollock encompassing the Aleutian Islands shelf region from 170°W to the U.S.-Russia Convention line; and the Central Bering Sea—Bogoslof Island pollock. These three management stocks probably have some degree of exchange. The Central Bering Sea—Bogoslof stock is a group that forms a distinct spawning aggregation that has some connection with the deep water region of the Aleutian Basin. In the Russian Exclusive Economic Zone (EEZ), pollock are thought to form two stocks, a western Bering Sea stock centered in the Gulf of Olyutorski, and a northern stock located along the Navarin shelf from 171°E to the U.S.- Russia Convention line. The northern stock is believed to be a mixture of eastern and western Bering Sea pollock with the former predominant. Bailey et al. (1999) present a thorough review of the population structure of pollock throughout the north Pacific region. Recent genetic studies using mitochondrial DNA methods have found the largest differences to be between pollock from the eastern and western sides of the north Pacific.

Previously, Ianelli et al. (1997) developed a model for Aleutian Islands pollock and concluded that the spatial overlap and the nature of the fisheries precluded a clearly defined "stock" since much of the catch was removed very close to the eastern edge of the region and appeared continuous with catch further to the east. In some years, a large portion of the pollock removed in the Aleutian Islands Region was from deep-water regions and appeared to be most aptly assigned as "Basin" pollock. This problem was confirmed in the 2003 Aleutian Islands pollock stock assessment (Barbeaux et al. 2003).

Fishery

The nature of the pollock fishery in the Aleutian Islands Region has varied considerably since 1977 due to changes in the fleet makeup and in regulations. During the late 1970s through the 1980s the fishing fleet was primarily foreign. In 1989, the domestic fleet began operating in earnest and continued in the Aleutian Islands Region until 1999 when the North Pacific Fishery Management Council (NPFMC) recommended closing this region for directed pollock fishing due to concerns for Steller sea lion recovery. Table 1A.1 provides a history of ABC, OFL, and catch for Aleutian Islands pollock since 1991. In 2005 the fishery was reopened with a 19,000 t TAC. A directed pollock fishery was conducted in February 2005, but the vessels participating in the fishery failed to find commercially harvestable quantities outside of Steller sea lion critical habitat closure areas and removed less than 200 t of pollock. In addition, bycatch rates of Pacific ocean perch were prohibitively high in areas where pollock aggregations were observed. The 2005 fishery is thought to have resulted in a net loss of revenue for participating vessels. Data on specific bycatch and discard rates for the 2005 fishery are not available due to issues of data confidentiality. In 2006 and 2007 the Aleut Corporation, in partnership with the Alaska Fisheries Science Center (AFSC), Adak Fisheries LLC and the owners and operators of the F/V Muir Milach, conducted the Aleutian Islands Cooperative Acoustic Survey Study (AICASS) to test the technical feasibility of conducting acoustic surveys of pollock in the Aleutian Islands using small (<32 m) commercial fishing vessels (Barbeaux, in press). This work was supported under an exempted fishing permit that allowed directed pollock fishing within Steller sea lion critical habitat. A total of 932 t and 1,100 t of pollock were harvested during these studies in 2006 and 2007 respectively, and biological data collected during the 2006 study were treated in the stock assessment as fishery data.

Data

Catch estimates

Estimates of pollock catch in the Aleutian Islands Region are derived from a variety of data sources (Table 1A.2). During the early period, the foreign-reported database (held at AFSC) is the main source of information and was used to derive the official catch statistics until about 1980 when the observer data were introduced to provide more reliable estimates. The foreign and joint-venture (JV) blend data takes into account observer data and reported catches and formed the basis of the official catch statistics until 1990. The NMFS Observer data are the raw observed catch estimates and provide an indication of the amount of catch observed relative to the current estimates from the blend data. Estimates of pollock discard levels have been available since 1990. During the years when directed fishing was allowed pollock discards represented a small fraction of the total catch (Table 1A.3).

The foreign reported catch database was used to partition catches among areas for the period 1977-1984, and the observer data were used to apportion catches from 1985-2003. These proportions were then expanded to match the total catch (Table 1A.4; Fig. 1A.1).

The distribution of observed catch differed between the JV fishery (1977-1989) and the domestic fishery (1989-2002; Fig. 1A.2). In the early period, the JV fishery operated in the deep basin area extending westward to Bowers Ridge and in the eastern most portions of the Aleutian Islands. Some operations took place out to the west but observer coverage was limited. In the recent period (1989-1998, since the Aleutian Islands Region has been closed to directed pollock fishing since 1999) the fishery was more dispersed along the Aleutian Islands chain with no observed catches along Bowers Ridge and fewer operations in the deep basin area. Considering the spatial distribution of these fisheries, we recommended that the Aleutian Islands Region be broken into areas where apparent breaks existed (Fig. 1A.3). These breaks separate the northern "basin" area from the Aleutian Islands chain and split the eastern-most portion of the Aleutian Islands Region from the Aleutian Islands. Two regional partitions were developed, one called NRA (for Near, Rat, and Andreanof Island groups) extending to 170°E, and another that excludes the eastern portion between 174°W and 170°W. The time series of catch estimates for these two groups is shown in Table 1A.5. In the NRA area west of 174°W the fishery tended to concentrate in two distinct locations, one on the north side of Atka Island around 174°W, and the other near 177°W northwest of Adak Island. While the overall catch level was relatively low, the fishery moved far to the west in 1998 (Fig. 1A.4).

Fishery length frequency

The number of hauls and length samples from the NRA region west of 174°W are quite small compared with the eastern and northern (basin) areas (Table 1A.6). Differences in the length frequencies appear to be substantial between regions (Barbeaux et al. 2004). During the early period, catches from the region west of 174°W longitude were composed of smaller fish. Catches from this region also tended to have a broader range of lengths. Fishery length frequency data from the Basin region were similar to the easternmost region and the Bogoslof region (during the years when a fishery was allowed there). In the 2005 stock assessment we investigated whether the changes in length frequency distributions for the NRA region west of 174°W could be attributed to seasonal differences in concentrations of fishing effort. These investigations showed that before 1990, the fishery tended to be more concentrated later in the year, but inter-annually the fishery was consistent in time between the eastern and western NRA (Barbeaux et al. 2005). We therefore concluded that differences in length distributions observed between these two regions could not be attributed to differences in the time of year in which the fishery was conducted. Intra-annual differences may show a trend that would be consistent with seasonality differences. The occurrence of larger fish later in the time series is likely due to the fishery targeting on spawning pollock. Pollock average weights-at-age from the early period are lower than the recent period (Table 1A.7). As shown in the 2005 assessment, the observed proportion of females in the catch appeared to show a slight decline over this period (Barbeaux et al. 2005).

Fishery age composition

Catch-at-age composition estimates were calculated following Kimura (1989) and modified by Dorn (1992). Briefly, length-stratified age data are used to construct age-length keys for each stratum and sex. These keys are then applied to randomly sampled catch length frequency data. The stratum-specific age composition estimates are then weighted by the catch within each stratum to arrive at an overall age composition for each year. Data were collected through shore-side sampling and by at-sea observers. The number of age samples and length samples was highly variable over this time period (Table 1A.8). This problem is exacerbated for samples collected from different areas and gears (Table 1A.9). Estimates of the catch-age compositions are shown in Table 1A.10. The age composition data collected in the 2006 AICASS were used as fishery data.

Survey data

Bottom trawl survey effort in the Aleutian Islands region has not been as extensive as in the eastern Bering Sea. The National Marine Fisheries Service in conjunction with the Fisheries Agency of Japan conducted bottom trawl surveys in the Aleutian Islands region (from ~165°W to ~170°E) in 1980, 1983, and 1986. The Alaska Fisheries Science Center's Resource Assessment and Conservation Engineering Division (RACE) conducted bottom trawl surveys in this region in 1991, 1994, 1997, 2000, 2002, 2004 and 2006. Biomass estimates from surveys conducted in the 1980s ranged between 309 and 779 thousand tons (mean 546 thousand t). Biomass estimates from the five most recent RACE surveys ranged between 112 and 366 thousand tons (mean 225 thousand t; Table 1A.11). The biomass estimates from the early surveys are not comparable with biomass estimates obtained from the RACE trawl surveys because of differences in the nets, fishing power of the vessels, and sampling design. In the early surveys, biomass estimates were computed using relative fishing power coefficients (RFPC) and were based on the most efficient trawl during each survey. Such methods result in pollock biomass estimates that are higher than those obtained using the standard methods employed in the RACE surveys. Plotted on a simple catch-per-tow basis, the relative distribution of pollock appears to be variable between years and areas (Fig. 1A.5).

The RACE Aleutian Islands bottom trawl (AIBT) surveys prior to 2004 indicate that most of the pollock biomass was located in the Eastern Aleutian Islands Area (Area 541), and along the north side of Unalaska-Umnak Islands in the eastern Bering Sea region (~165°W and 170°W). The 2004 Aleutian Islands trawl survey showed the highest density and estimated biomass levels in the Unalaska-Umnak area in the eastern Bering Sea region. However, the 2006 survey observed only low densities of pollock in the Unalaska-Umnak Islands area. If we ignore the biomass estimates from the Unalaska-Umnak area, the 2004 and 2006 AIBT surveys are very similar and show a very different pattern of biomass abundance relative to the 2002 survey (Fig. 1A.5). Within the Aleutian Islands Region (Areas 541, 542, and 543), the 2002 AIBT survey indicated the highest densities and estimated biomass levels in the Central Aleutian Islands Area (Area 542), followed by the Eastern (Area 541) and Western areas (Area 543). The 1991-2000 AIBT surveys indicated the highest estimated biomass levels from the NRA Areas was observed in Area 541 followed by Area 542 and Area 543. The earlier RACE AIBT surveys indicated a decline in pollock biomass in the portion of Area 541 east of 174°W longitude from a high of 53,865 t in 1991 to a low of 28,985 t in the 2000 survey. This trend was reversed beginning in the 2002 survey with estimates of 53,368 t, 111,250 t, and 69,522 t from the 2002, 2004, 2006 surveys, respectively (Table 1A.11). During the 1991-2002 surveys, a number of large to medium-sized tows were encountered throughout the Aleutians indicating a fairly well distributed population. This is very different from the 2004 and 2006 survey estimates which indicated a low level of pollock abundance in both Area 542 and Area 543, and a much higher pollock density in Area 541. The 2004 survey revealed very few pollock throughout the NRA, except for a single large tow in Seguam pass. The distribution of pollock in the 2006 survey revealed a similar pattern to that of the 2004 survey with high CPUE in the Seguam pass area. The 2006 survey found a higher concentration of pollock in the Delerof Islands that was not observed in 2004, but is consistent with aggregations observed in 2002. Similar to the 2004 survey, there were very few pollock observed west of 180° longitude. Given that there has not been a substantial fishery in the Aleutians since 1999, nor has there been a substantial change in survey methodology or design, the continued decrease in pollock must be attributed to either a change in catchability due to vertical migration of pollock out of the reach of the bottom trawl, increased emigration of pollock out of the surveyed area, decreased recruitment, increased natural mortality exceeding recruitment, or some combination of these factors. Since the AIBT is limited to within the 500 m isobath, the survey biomass estimates do not include mid-water pollock, nor do they include pollock located offshore of the 500 m isobath. Survey biomass estimates therefore represent an unknown portion of the total biomass. The biomass in the Aleutian Islands may be under-estimated if the on-bottom/off-bottom distribution is similar to that of the eastern Bering Sea (Ianelli et al. 2005). In addition, climatic and year class variation may cause differences in the proportion of pollock available to the bottom trawl survey.

Last year we looked at distribution patterns of pollock in relation to temperature and depth. We found that in comparison with pollock distributions observed in the 2004 Bering Sea and 2005 Gulf of Alaska bottom trawl surveys (BSBTS and GOABTS respectively), the distributions observed in the 2004 and 2006 AIBTS were in a more limited temperature range and generally deeper (Fig. 1A.6). Overall, the bottom temperatures in the AIBTS were much less variable than in either the BSBTS or GOABTS at depth. The AIBTS bottom temperatures ranged between the bottom temperatures of other surveys, with the BSBTS generally cooler at depth and GOABTS warmer at depth. In the AIBTS, the highest concentrations of pollock are encountered between 140 m and 300 m, while in the BSBTS, the highest concentrations of pollock were above 100 m and above 150 m in the GOABTS. The 2006 AIBTS was colder at shallower depths than in 2004 and pollock concentrations appeared to shift towards deeper water (Fig. 1A.7). The shift of pollock distribution to deeper waters with colder bottom temperatures is consistent with a shift observed in the Bering Sea between 1999, a cold year, and 2004, a warm year (Fig. 1A.8).

Survey Length Frequencies

There are apparent differences in pollock length-at-age between the Aleutian Islands, Bering Sea, and Gulf of Alaska between ages 2 and 9, with the Aleutian Islands pollock being the largest, followed by the GOA, and Bering Sea pollock the smallest at age (Fig. 1A.9). The pollock length frequency collection from the 2006 AIBTS showed the primary mode between 56 and 66 cm, similar to previous years and is thought to be primarily composed of 2000 and/or 1999 year-class fish (Fig. 1A.10). There was a small mode between 15 and 25 cm that would be consistent with 1 or 2 year old fish, but much fewer than observed in 2004. The 2004 AIBT survey found a large proportion of small fish (between 10 and 25 cm, indicative of 1 or 2 year old fish) in the NRA area west of 174°W, but very few small fish east of 174°W. The 2002 AIBT survey did not find very many small fish anywhere in the Aleutians. There were a large number of small fish observed in the 1994 and 2000 surveys throughout the NRA . The large numbers of 1 or 2 year old size pollock observed in the these surveys were assumed to have entered the fishable population in 1996 and 2002, respectively, and should have stabilized or increased pollock biomass in the Aleutian Islands in recent years.

Other Surveys

In addition to the bottom trawl survey there has been one echo integration-trawl survey in a portion of the NRA. The R/V Kaiyo Maru conducted a survey between 170°W and 178°W longitude in the winter of 2002 after completing a survey of the Bogoslof region (Nishimura et al 2002; Fig. 1A.11). Due to difficulties in operating their large mid-water trawl on the steep slope area, they determined that their biological sampling in this area were insufficient for accurate species identification and biomass estimation. They did, however, present preliminary biomass estimations. For the entire area from 170°W and 178°W longitudes they estimated a biomass of 93,000 t of spawning pollock biomass with between 61,000 t estimated in the NRA east of 173°W, and 32,000 t in the remainder of the survey area to 178°W longitude (Table 1A.12). The largest aggregations of pollock in the NRA area were observed at 174°W longitude north of Atka Island. Most of the pollock echo sign was observed along the slope of the Aleutian Islands and relatively near shore.

In 2006 and 2007 acoustic survey studies were completed aboard a 32m commercial trawler (F/V Muir Milach) equipped with a 38kHz SIMRAD ES-60 acoustic system. The AICASS was conducted to assess the feasibility of using a small commercial fishing vessel to estimate the abundance of pollock in waters off the central Aleutian Islands (Fig. 1A.12). To verify the acoustic data and to support the study, 1,000 t and 3,000 t of groundfish were allocated to be harvested within an area that included waters within 20 nautical miles (nm) of Steller sea lion haulouts in 2006 and 2007 respectively. In 2006, six acoustic surveys were successfully conducted between 14 March and 4 April 2006. The area from North Cape of Atka Island to Koniuji Island (~1 degree longitude) was surveyed three times, while a smaller subset of this area was surveyed on three other occasions (Fig. 1A.13 and Fig. 1A.14). The three larger surveys (180 nm^2 with transect spacing of 1.5 nm) were conducted in the beginning (Survey 2), middle (Survey 4), and end (Survey 8) of the study period. Survey 5 was conducted parallel to the shelf break and covered only 9 nm2 (with transects spaced at 0.5 nm). This survey provided data useful for geostatistical analyses. Surveys 6 and 7 covered 72 nm^2 with 1.0 nm transect and occurred in the middle of the large survey area coincident with the highest density of pollock. Survey 2, conducted 14-15 March 2006, provided a biomass estimate for pollock of 8,910 t. The biomass estimate for subsequent surveys were lower (although not statistically significantly lower for Survey 4) and dropped significantly after Survey 4 to a low of 2,845 t for the final survey (Fig. 1A.15 and Fig. 1A.16). A total of 905 t of pollock were harvested during the 2006 study, no other directed pollock fishing was conducted in the Aleutian Islands in 2006. In 2007 two acoustic surveys were conducted, the first was completed between March 18 and March 24 2007 and the second between April 8 and April 15 2007. For both 2007 surveys, the region between 173° and 179° W longitude was surveyed at 2.5 nm transect spacing perpendicular to the shelf break one mile inland from the break and five miles offshore of the break or until pollock sign was no longer observed. Quantitative survey results for 2007 are not yet available, but early qualitative evaluations suggest pollock abundance similar to the latter 2006 surveys. Of the 3,000 t allocated for the study only 1,300 t were harvested, further suggesting low pollock abundance in the central Aleutian Islands area.

Analytic Approach

The 2007 Aleutian Islands walleye pollock stock assessment uses the same modeling approach as in last year's assessment; implemented through the Assessment Model for Alaska (here referred to as AMAK). AMAK is a variation of the "Stock Assessment Toolbox" model presented to the plan team in the 2002 Atka mackerel stock assessment, with some small adjustments to the model and a user-friendly graphic interface.

The abundance, mortality, recruitment, and selectivity of the Aleutian Islands pollock were assessed with a stock assessment model constructed with AMAK as implemented using the ADMB software. The ADMB is a C++ software language extension and automatic differentiation library. It allows for estimation of large numbers of parameters in non-linear models using automatic differentiation software developed into C++ libraries (Fournier 1998). The optimizer in ADMB is a quasi-Newton routine (Press et al. 1992). The model is determined to have converged when the maximum parameter gradient is less than a small constant (set to 1 x 10^{-7}). A feature of ADMB and AMAK is that it includes post-convergence routines to calculate standard errors (or likelihood profiles) for quantities of interest.

Model structure

The AMAK model models catch-at-age with the standard Baranov catch equation. The population dynamics follows numbers-at-age over the period of catch history with natural and age-specific fishing mortality occurring throughout the 14-age-groups that are modeled (ages 2-15+). Age-2 recruitment in each year is estimated as deviations from a mean value expected from an underlying stock-recruitment curve. Deviations between the observations and the expected values are quantified with a specified error model and cast in terms of a penalized log-likelihood. This overall log-likelihood (L) is the weighted sum of the calculated log-likelihoods for each data component and model penalties. The component weights are inversely proportional to the specified (or in some cases, estimated) variances. Appendix Tables 1 –3 in Barbeaux et al. (2005), provide a description of the variables used, and the basic equations describing the population dynamics of Aleutian Islands pollock and likelihood equations. The model was modified from that of Barbeaux et al. (2003). These modifications include a feature that allows a user-specified age-range for which to apply the survey (or other abundance index) catchability. For example, specifying the age-range of 6-10 (as was done for Aleutian Islands Atka mackerel) means that the average age-specific catchability of the survey is set to the parametric value (either specified as fixed, as in this assessment, or estimated). Also, in the 2003 assessment age-1 pollock were explicitly modeled, whereas in the work presented here, they were dropped from consideration because observations of age-1 pollock are irregular, and in trials where they were included, they were found to limit the flexibility to incorporate alternative model specifications such as parametric forms of selectivity functions. The quasi[1] likelihood components and the distribution assumption of the error structure are given below:

Likelihood Component	Distribution Assumption
Catch biomass	Lognormal
Catch age composition	Multinomial
Survey catch biomass	Lognormal
Survey catch age composition	Multinomial
Recruitment deviations	Lognormal
Stock recruitment curve	Lognormal
Selectivity smoothness (in age-coefficients, survey and fishery)	Lognormal
Selectivity change over time (fishery only)	Lognormal
Priors (where applicable)	Lognormal

The age-composition components are heavily influenced by the sample size assumptions specified for the multinomial likelihood. Since sample variances of our catch-at-age estimates are available (Dorn 1992), "effective sample sizes" ($\dot{N}_{i,j}$) can be derived as follows (where i indexes year, and j indexes age):

$$\dot{N}_{i,j} = \frac{p_{i,j}\left(1-p_{i,j}\right)}{\mathrm{var}\left(p_{i,j}\right)}$$

where $p_{i,j}$ is the proportion of pollock in age group j in year i plus an added constant of 0.01 to provide some robustness. The variance of $p_{i,j}$ was obtained from the estimates of variance in catch-at-age. Thompson et al., (2003, p. 137) and Thompson (AFSC pers. comm.) note that the above is a random variable that has its own distribution. Thompson (2003) shows that the harmonic mean of this distribution

[1] The likelihood is *quasi* because model penalties (e.g., non-parametric smoothers) are included.

is equal to the true sample size in the multinomial distribution. This property was used to obtain sample size estimates for the surveys and fishery numbers-at-age estimates:

Fishery data	Year	1978	1979	1980	1981	1982	1983	1984	1985	1987
	$\dot{N}_{i,\bullet}$	246	170	119	215	553	81	296	225	150
	Year	1990	1992	1993	1994	1995	1996	1997	1998	2006
	$\dot{N}_{i,\bullet}$	199	238	172	327	211	228	30	302	300
Survey data										
	Year	1991	1994	1997	2000	2002	2004	2006		
	$\dot{N}_{i,\bullet}$	1*	740	690	831	1124	774	508		

*The 1991 value was down-weighted by a factor of 1,000 because the samples collected in that year were not representative of the region considered.

Parameters

Parameters estimated independently

Natural Mortality

For two base models (Model 1 and Model 2A) a natural mortality value of 0.2 was used. Last years stock assessment (Barbeaux et al. 2006) suggested that Aleutian Islands pollock is less productive than the Eastern Bering Sea stock and therefore M = 0.2 would be more appropriate. In previous stock assessments we assumed a value of M = 0.3 based on the studies of Wespestad and Terry (1984) for the Bering Sea (Table 1A.14). The current assessment model does not allow for age-specific natural mortality rates. It should be noted that in general, a higher natural mortality rate for age 2 pollock may be more appropriate (e.g., Ianelli et al. 2003,) and that this model differs from the Eastern Bering Sea model in this manner. In the future, we will be investigating methods to improve AMAK to include age varying natural mortality.

Length and Weight at Age

We estimated length and weight-at-age separately for the survey and for the fishery. We obtained survey estimates from AIBT surveys and computed fishery estimates from observer data and the 2006 AICASS. The von Bertalanffy growth curve parameters and length-weight regression parameters from the 1980 to 2004 surveys are given in Table 1A.15. Survey weight-at-age values from 1978 to 2007 are given in Table 1A.16. For the time period 1978 to 1990, survey length and weight at age estimates were derived from the 1980, 1983, and 1986 AIBT surveys (Table 1A.15). For the time period 1990 to 2006 we calculated length and weight-at-age values from the 1991, 1994, 1997, 2000, 2002, 2004, and 2006 AIBT surveys. We calculated the average length-at-age as weighted averages by age and calculated the length-weight relationships using linear regression analysis. Data for these analyses were retrieved from the Resource Assessment and Conservation Engineering Division's (RACE) survey database. For years without survey length and weight-at-age data (unshaded cells in Table 1A.16), we used the mean values at age from the two nearest surveys (Table 1A.13). Fishery weight-at-age values from 1978 to 2006 are shown in Table 1A.17. Fishery data east of 174°W longitude were excluded from the data set for calculating length and weight-at-age. For the fishery, we used year (when available) and age-specific estimates of average weights-at-age computed from the fishery age and length sampling programs from data collected west of 174°W. These values (Table 1A.17) are important for converting model estimated catch-at-age (in numbers) to estimated total annual harvests (by weight).

Maturity at Age

The maturity at age schedule is based on the studies of Wespestad and Terry (1984; Table 1A.18). An updated analysis of maturity-at-age using more recent data was presented in the 2005 Bering Sea pollock stock assessment. However,since the EBS data collected in 2002 and 2003 are in agreement with that observed by Westpestad and Terry (1984), a change in model configuration is not warranted at this time.

Parameters estimated conditionally

Deviations between the observations and the expected values are quantified with a specified error structure. Lognormal error is assumed for estimates of survey and fishery catch, and a multinomial error structure is assumed for analysis of the survey and fishery age compositions. These error structures are used to estimate the following parameters conditionally within the model.

Fishing Mortality

Fishing mortality in all models was parameterized to be separable with both an age component (selectivity) and a year component. In all models selectivity is conditioned so that the mean value over all ages will be equal to one. To provide regularity in the age component, a penalty was imposed on sharp shifts in selectivity between ages using the sum of squared second differences. In addition, the age component parameters are assumed constant for the last 4 age groups (ages 12-15). Finally, selectivity was allowed to vary over time. The model was set with controls selecting the degree to which selectivity is allowed to change between ages and over time.

Survey Catchability

For the bottom trawl survey, survey catchability-at-age follows the parameterization similar to the fishery selectivity-at-age presented above. The catchability-at-age relationship is modeled with a smoothed non-parametric relationship that can take on any shape (with penalties controlling the degree of change and curvature specified by the user). To provide regularity in the age component, a penalty was imposed on sharp shifts in catchability-at-age between ages using the sum of squared second differences. In addition, the age component parameters are assumed constant for the last 4 age groups (ages 12-15). As noted above, the model allows specification of the age-range over which the catchability parameter is applied. For Aleutian Islands pollock, ages 6-10 were selected to have the average catchability (factoring selectivity components) equal to the catchability parameter value.

In the 2004 Aleutian Islands pollock stock assessment, the focus of our analysis was to evaluate a key model assumption: the extent to which the NMFS summer bottom trawl survey catchability should be estimated by the available data (resulting in very high stock sizes) or constrained to be close to a value of 1.0 (implying that the area-swept survey method during the summer months reasonably applies to a fishery that will likely occur during the winter). We provided evidence that suggests that fixing the value of survey catchability to 1.0 is unreasonable. However, recognizing that no other information is available to “anchor” the assessment model to an absolute biomass level, the authors were reluctant to proceed with specifying influential prior distributions on catchability values. The effects of the fishery on the pollock population dynamics appear to be poorly determined given the available data. This could be due to a number of factors including: characteristics of Aleutian Islands pollock relative to adjacent regions, poor quality data, and the possibility that the fishing effects are minor relative to other factors. The latter point is likely to be true at least for the recent period since 1999 when the fishery removals have been minor. Therefore, we assumed a fixed catchability value of 1.00 for our 2007 preferred alternative models.

Recruitment

We used a re-parameterized form of the Beverton-Holt stock recruitment relationship based on Francis (1992). Values for the stock recruitment function parameters α and β are calculated from the values of R_0 (the number of 0-year-olds in the absence of exploitation and recruitment variability) and the “steepness” (h) of the stock-recruit relationship. The “steepness” parameter is the fraction of R_0 to be expected (in the absence of recruitment variability) when the mature biomass is reduced to 20% of its pristine level (Francis 1992). As an example, a value of h = 0.8 implies that at 20% of the unfished spawning stock size will result in an expected value of 80% of the unfished recruitment level. The steepness parameter (h) was estimated with a prior of 0.7 and CV of 0.2, and sigma r was set at 0.6 for all model runs.

Natural Mortality

For the reference model, natural mortality (M) was estimated within the model using an uninformative prior starting with a value of 0.3 with a *CV* of 0.2. The addition of the 2006 catch-at-age data from the 2006 AICASS in the 2006 assessment (Barbeaux et al. 2006), allowed for improved model stability while estimating natural mortality.

Model evaluation

Four models were evaluated for this year's stock assessment (Model 1, Model 2A, Model 2B, and Model 2C). All four models are configured with a survey catchability of 1.0, a stock recruitment steepness parameter centered on 0.7 with a *CV* of 0.2 as a (normal) prior distribution and sigma r of 0.6. The data configuration for the four models differ in that Model 1 contains only survey data from the NRA area west of 174º W longitude, and Models 2A, 2B, and 2C contain survey data from the entire NRA region. Model 2A differs from Model 2B and Model 2C in that natural mortality is set at 2.0 in Model 2A, but is estimated within Model 2B and Model 2C with a prior of 0.3 and *CV* of 0.2. Models 1, 2A, and 2B have the same parameterization as Models 1, 2A, and 2B in the 2006 Aleutian Islands pollock stock assessment, with the addition of the 2007 catch data and 2006 AI bottom trawl survey catch-at-age estimates. Model 2C is the same as Model 2b except the recruitment was modeled using data from 1978-2007.

Relative differences in model fits are shown in Table 1A.19 and key results are presented in Table 1A.20. By including the survey biomass from the area east of 174°W Models 2A, 2B, and 2C show a marked improvement in fit relative to Model 1, based on lowest quasi-likelihood. This is primarily due to a better fit to the survey index, but Models 2A, 2B, and 2C provide a better fit to all of the data components. A better fit to the survey index by Models 2A, 2B, and 2C can be attributed to the lower intra-annual variability in the NRA-wide biomass estimates with a much smoother trend which allows for a better fit to the model. The results from the 2004 and 2006 summer bottom trawl surveys are not consistent with the assumed stock delineation proposed in Model 1, and further analyses are needed to determine a tenable stock delineation. Model 2B estimates natural mortality internally which improves the model fit over Model 2A. In particular, Model 2B provides an improved fit to the age composition data for both the survey and fishery. Modeling recruitment from 1978-2007 in Model 2C degrades the overall fit to the catch-at-age data.

The fit to the survey data is relatively poor for all four models, but not surprisingly so, given the estimates of variance for the individual survey point estimates and the high intra-annual variability of these estimates. The fit to the survey age composition data was excellent for all models, except for the 1991 data which, for sampling reasons, was given less weight than for the other years. Results of fits to the fishery age-composition data were much poorer. There is high variability in the age data which probably reflects the diversity in sampling locations for the fishery in different years. The time-varying selectivity patterns estimated by the models show only slight changes for the survey, but a relatively large shift (to older fish) after 1990 for the fishery data, coinciding with the change from a foreign fishery to a domestic fishery targeting spawning aggregations. The estimated total biomass trends for the four models diverge considerably (Fig. 1A.17). Differences between Model 1 and Model 2A are due to differences in the survey estimates for the two areas, differences between Model 2A and Model 2B are due to the higher estimated natural mortality in Model 2B. Differences of fit between Model 2B and 2C are due differences in the variability of recruitment between the two models. Results of MCMC simulations for Model 2B show that the natural mortality estimate is stable with a mode of 0.218 and a mean of 0.235 and *CV* =

0.10 (Table 1A.2, Fig. 1A.18, and Fig. 1A.19). The lower estimate of natural mortality than that estimated for Bering Sea pollock is supported by estimates of M = 0.26 for Bogoslof area pollock estimated by Ianelli et al. (2005), and an estimate of M = 0.2 for Aleutian Basin pollock by Wespestad and Terry (1984).

We chose Model 2B as the reference model because of the improved fit (lowest negative quasi-likelihood) to the available data and stable estimate for M. Fits to the survey index, survey age composition, fishery age composition, and selectivity trend for Model 2B are shown in Fig. 1A.20, Fig. 1A.21, Fig. 1A.22, and Fig. 1A.23 respectively. As stated above, Model 2B fit the bottom trawl survey index is better than Model 1, but the fit remains relatively poor, and the model has difficulty fitting the low 1994 survey index in light of the high level of catch observed in 1995 and the increase in the survey index in 1996. The model predicts a decline in abundance that corresponds with the high fishing mortality observed in the mid- to late-1990s. Model 2B fits the survey and fishery age composition data relatively well.

Results

Abundance and exploitation trends

As indicated in the 2004 stock assessment analysis (Barbeaux et al, 2004), the abundance trend is highly conditioned on the assumptions made about the area-swept survey trawl catchability. Even with catchability fixed at 1.0, the uncertainty in the trend and level is very high. Bearing in mind the high degree of uncertainty, the total biomass trend (Table 1A.14 and Fig. 1A.24) appears to have increased from 1999 to 2004 after cessation of directed fishing in the area, but from 2005 to 2007 was stable to decreasing. In this assessment, total biomass includes pollock at age 2 and above.

Estimated pollock numbers in age from 1978 to 2007 for reference Model 2B are given in Table 1A.24.

Spawning biomass appears to have been greatly influence by the high exploitation in the late 1990s (Fig. 1A.25). The highest fishing mortality occurred in 1995 (F = 0.722 and Catch/biomass = 0.20) when the fishery harvested more than 75% of the 1994 survey biomass estimate (Table 1A.23). The reference model shows continued higher than average exploitation in 1997 and 1998 with F = 0.69 and F=0.68 respectively. The spawning biomass has been increasing since 2000.

Recruitment

Estimates of recruitment (at age 2) are estimated with high variance (Table 1A.24 and Table 1A.25 , Fig. 1A.26). The 1978 year-class is the largest (300 million age 2 recruits). The 1989 year class is the second largest (134 million age 2 recruits), and the 2000 year class is the third largest (107 million age 2 recruits). Whether AI pollock recruitment is synchronous with other areas is an open question (e.g., the 1978, 1989, and 2000 year classes are also strong in the EBS region, Ianelli et al. 2005). An alternative explanation is that movement between other areas may affect year-class abundance. The extent to which adjacent stocks interact is an active area of research.

Projections and harvest alternatives

For projection purposes we use the yield projections estimated for reference Model 2B. Because a directed fishery on pollock was banned between 1999 and 2004, and because the 2005 through 2007 fisheries were greatly limited, we do not believe the 2007 AI pollock selectivity-at-age assumed in these models would be relevant to a fully utilized directed fishery. For projections, we used the 2005 selectivity-at-age derived from the 2006 EBS pollock assessment (Ianelli, et al 2006), because a current estimate for selectivity-at-age for a directed pollock fishery in the Aleutians is not available (Table 1A.26). The selectivity-at-age for the EBS pollock would be applicable if an Aleutian Islands Pollock fishery was prosecuted by EBS pollock fishing vessels. Catchability for the reference Model 2B is fixed at 1.0. We note that the reference model excludes fishery data from east of 174°W longitude, but includes all AIBTS data from west of 170°W longitude.

Reference fishing mortality rates and yields

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC (*max* F_{ABC}). The fishing mortality rate used to set ABC (F_{ABC}) may be less than or equal to this maximum permissible level. The overfishing and maximum allowable ABC fishing mortality rates are given in terms of percentages of unfished female spawning biomass ($F_{SPR\%}$), on fully selected age groups. The associated long-term average female spawning biomass that would be expected under average estimated recruitment from 1990-2003 for Model 2B (54.67 million age 2 fish) and F equal to $F_{40\%}$ and $F_{35\%}$ are denoted $B_{40\%}$ and $B_{35\%}$, respectively. We chose to exclude the 1978 extreme recruitment event, treating it as an anomalous event and therefore allowing a more conservative estimate of future recruitment. The Tiers require reference point estimates for biomass level determinations. We present the following reference points for NRA pollock for Tier 3 of Amendment 56. For our analyses, we estimated the following values from Model 2B:

Female spawning biomass	Model 2B
$B_{100\%}$	128,620 t
$B_{40\%}$	51,450 t
$B_{35\%}$	45,020 t
B_{08}	82,250 t

Specification of OFL and Maximum Permissible ABC

For Model 2B, the projected year 2008 female spawning biomass (SB_{08}) is estimated to be 82,250 t, above the $B_{40\%}$ value of 51,450 t placing NRA pollock in Tier 3a. The maximum permissible ABC and OFL values under Tier 3a are:

Model 2B Tier 3a:

Harvest Strategy	FSPR%	Fishing Mortality Rate	2007 Projected yield (t)
max F_{ABC}	$F_{40\%}$	0.196	28,160 t
F_{OFL}	$F_{35\%}$	0.244	34,040 t

If the estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ are not reliable, then under Tier 5 with new model estimated natural mortality of 0.218, the 2008 ABC would be 15,530 t (94,992 t x 0.75 x 0.218 = 15,530 t) and under Tier 5 with an assumed natural mortality of 0.3 the 2008 ABC would be 21,370 t.

ABC Considerations and Recommendation

ABC Considerations

There remains considerable uncertainty in the Aleutian Islands pollock assessment. We've noted some concerns below:

1) The level of interaction between the Aleutian stock and the Eastern Bering Sea stock is unknown. It is evident that some interaction does occur and that the abundance and composition of the eastern portion of the Aleutian Islands stock is highly confounded with that of the Eastern Bering Sea stock. Overestimation of the Aleutian Islands pollock stock productivity due to an influx of Eastern Bering Sea stock is a significant risk.

2) As assessed in the 2004 AI pollock stock assessment (Barbeaux et al. 2004), AIBT survey catchability is probably less than 1.0, but we have no data to concretely anchor the value at anywhere less than 1.0. We therefore employ a default value for catchability of 1.00. This provides a conservative total biomass estimate.

3) AIBT survey estimates of biomass are uncertain with an average CV of 0.36. The 2002, 2004, and 2006 estimates are especially uncertain with CVs of 0.38, 0.78, and 0.48 respectively. This results in considerable uncertainty in the projections.

ABC Recommendations

The pollock spawning stock biomass in the NRA appears to be increasing, even in light of the latest low values for the AIBT survey. The total biomass appears to be stable. The estimated female spawning biomass projected for 2008 is 82,250 t. The projected total age 3+ biomass for 2008 is 197,280 t. The maximum permissible 2008 ABC based on $F_{40\%}$ = 0.196 is 28,160 t.

Standard Harvest Scenarios and Projection Methodology

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3, of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2007 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2008 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2007. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2008, are as follows (a "*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2008 recommended in the assessment to the *max* F_{ABC} for 2008. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 2003-2007 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, *F* is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to FOFL. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2008 or 2) above ½ of its MSY level in 2009 and above its MSY level in 2008 under this scenario, then the stock is not overfished.)

Scenario 7: In 2008 and 2009, *F* is set equal to *max* F_{ABC}, and in all subsequent years, *F* is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2020 under this scenario, then the stock is not approaching an overfished condition.)

The author included one more scenario in order to take into consideration of the Congressionally mandated TAC cap on pollock harvest from the Aleutian Islands area.

Scenario 8: In 2008 through 2020 the TAC is increased to 19,000 t. (Rationale: 19,000 is the AI pollock cap set by Congressional mandate).

Projections and status determination

The projected yields, female spawning biomass, and the associated fishing mortality rates for the seven harvest strategies for the reference model are shown in Table 1A.15. Under a harvest strategy of $F_{40\%}$ (Scenario 1), female spawning biomass is projected to be above $B_{40\%}$ for all 13 years of the projection Fig. 1A.25 and Table 1A.26. Female spawning biomass is projected to fall below $B_{40\%}$ when fishing at F_{OFL} (Table 1A.26) in 2011 (Scenario 6) and 2012 (Scenario 7) and remain below for the remainder of the projection. Please note again that the fishing mortality rates are prescribed on the basis of the harvest scenario and the spawning biomass in each year. Thus, fishing mortality rates may not be constant within the projection if spawning biomass drops below $B_{40\%}$ in any run.

The associated long-term average female spawner biomass that would be expected under average estimated recruitment from 1990-2003 (54.67 million age 2 fish) and $F = F_{35\%}$, denoted $B_{35\%}$ is estimated to be 45,020 t. This value ($B_{35\%}$), is used in the status determination criteria. Female spawning biomass for 2008 (82,250 t) is projected to be above $B_{35\%}$ thus, the NRA pollock stock would be determined to be *above* its minimum stock size threshold (MSST) and is *not overfished*. Female spawning biomass for 2010 is projected to be above $B_{35\%}$ in scenario 7, thus the NRA pollock stock is *not* expected to fall below its MSST in two years and is *not approaching an overfished condition*.

Projections under scenario 8 (Fig. 1A.27, Fig. 1A.28, and Table 1A.26), show that a constant harvest of 19,000 t through 2020 would be a conservative harvest strategy under Model 2B, resulting in $F_{2008} = 0.13$ increasing to $F_{2020} = 0.20$, and a decreasing spawning biomass trajectory approaching $B_{40\%}$ by 2020.

Ecosystem Considerations

Pollock is a commercially important species which is also important as prey to other fish, birds, and marine mammals, and has been the focus of substantial research in Alaskan ecosystems, especially in the Gulf of Alaska (GOA; e.g. Hollowed et al 2000). To determine the ecosystem relationships of juvenile and adult pollock in the Aleutian Islands (AI), we first examine the diet data collected for pollock. Diet data are collected aboard NMFS bottom trawl surveys in the AI ecosystem during the summer (May – August). In the AI, a total of 1458 pollock stomachs were collected between the 1991 and 1994 bottom trawl surveys (n=688 and 770, respectively) and used in this analysis. The diet compositions reported here reflect the size and spatial distribution of pollock in each survey (see Appendix A, “Diet calculations” for detailed methods from Barbeaux et al. 2006). Juvenile pollock were defined as fish less than 20 cm in length, which roughly corresponds to 0 and 1 year old fish in the stock assessment, and adult pollock were defined as fish 20 cm in length or greater, roughly corresponding to age 2+ fish.

In the AI, pollock diet data reflects a closer connection with open oceanic environments than in either the Eastern Bering Sea (EBS) or the GOA. Similar to the other ecosystems, euphausiids and copepods together make up the largest proportion of AI adult pollock diet (29% and 19%, respectively); however, it is only in the AI that adult pollock rely on mesopelagic forage fish in the family Myctophidae for 24% of their diet, and AI juvenile pollock have a lower proportion of euphausiids and a higher proportion of gelatinous filter feeders than in the GOA or EBS (Fig. 1A.29, left panels). We can take this diet composition information and convert it to broad ranges of tons consumed annually by pollock in the AI using the Sense routine (Aydin et al. in review), which incorporates information on pollock consumption derived from the stock assessment (see Appendix A, “ration calculations” for detailed methods), as well as uncertainty in all other food web model parameters. As estimated by the Sense routine, AI adult pollock consumed between 100,000 and 900,000 metric tons of euphausiids annually during the early 1990s, with similar ranges of myctophid and copepod consumption. Juvenile AI pollock consumed an additional estimated 100,000 to 900,000 tons of copepods per year (Fig. 1A.29, right panels).

Using diet data for all predators of pollock and consumption estimates for those predators, as well as fishery catch data, we next estimate the sources of pollock mortality in the AI (see detailed methods in Appendix A). Sources of mortality are compared against the total production of pollock as estimated in the AI pollock stock assessment model. In the AI, integration of this single species information with predation within the food web model suggests that most adult pollock mortality was caused by the pollock trawl fishery during the early 1990s (48%; Fig. 1A.30, left panels). (Fishery catch of pollock in the AI has subsequently declined to less than half the early 1990s catch by the late 1990s, and the directed fishery was closed in 1999 (Ianelli et al. 2005). Therefore, AI pollock likely now experience predation mortality exceeding fishing mortality as in the EBS and GOA ecosystems.) The major predators of AI adult pollock are Pacific cod, Steller sea lions, pollock themselves, halibut, and skates. In the AI, juvenile pollock have a very different set of predators from adult pollock; Atka mackerel cause most juvenile pollock mortality (71%). Estimates of the tonnage of adult pollock consumed by predators from the Sense routines (Aydin et al in review) ranged from 8,000 to 27,000 tons consumed by cod annually during the early 1990s, while Atka mackerel were estimated to consume between 75,000 and 410,000 tons of juvenile pollock annually in the AI ecosystem (Fig. 1A.30, right panels).

After reviewing the diet compositions and mortality sources of pollock in the AI, we shift focus slightly to view pollock and the pollock fishery within the context of the larger AI food web. When viewed within the AI food web, the pollock trawl fishery (in red; Fig. 1A.31) is a relatively high trophic level (TL) predator which interacts mostly with adult pollock, but also with many other species (in green; Fig. 1A.31). The diverse pollock fishery bycatch ranges from high TL predators such as salmon sharks, sleeper sharks, and arrowtooth flounder, to mid TL pelagic forage fish and squid, to low TL benthic invertebrates such as crabs and shrimp, but all of these catches represent extremely small flows. Because the pollock trawl fishery contributes significant fishery offal and discards back into each ecosystem, these flows to fishery detritus groups are represented as the only “predator consumption” flows from the fishery; the biomass of retained catch represents a permanent removal from the system.

In the AI food web model, we included detailed information on bycatch for each fishery. This data was collected in the early 1990s when the AI pollock fishery was much larger than it is at present. During the early 1990’s, the pollock trawl fishery was extremely species-specific in the AI ecosystem, with pollock representing over 90% of its total catch by weight (Fig. 1A.32). No single bycatch species accounted for more than 1% of the catch. Although these catches are small in terms of percentage, the high volume pollock fisheries still account for the majority of bycatch of pelagic species in the BSAI management areas, including smelts, salmon sharks, and squids (Gaichas et al. 2004).

The intended target of the pollock trawl fishery is also a very important prey species in the wider AI food web. When both adult and juvenile pollock food web relationships are included, over two thirds of all species groups turn out to be directly linked to pollock either as predators or prey in the food web model (Fig. 1A.33). In the AI, the significant predators of pollock (blue boxes joined by blue lines) include halibut, cod, Alaska skates, Steller sea lions, and the pollock trawl fishery. Significant prey of pollock (green boxes joined by green lines) are myctophids, euphausiids, copepods, benthic shrimps, and amphipods, with juveniles preying on the euphausiids and copepods.

We can investigate whether these differences in pollock diet, mortality, and relationships between the EBS and AI might suggest different ecosystem roles for pollock in these areas. We use the diet and mortality results integrated with information on uncertainty in the food web using the Sense routines (Aydin et al. in review) and a perturbation analysis with each model food web to explore the ecosystem relationships of pollock further. Two questions are important in determining the ecosystem role of pollock: which species groups are pollock important to, and which species groups are important to pollock?

First, the importance of pollock to other groups within the AI ecosystem was assessed using a model simulation analysis where pollock survival was decreased (mortality was increased) by a small amount, 10%, over 30 years to determine the potential effects on other living groups. This analysis also incorporated the uncertainty in model parameters using the Sense routines, resulting in ranges of possible outcomes. Figure 1A.34 shows the resulting percent change in the biomass of each species after 30 years for 50% of feasible ecosystems with 95% confidence intervals (error bars in Figure 1A.34). Species showing the largest median changes from baseline conditions are presented in descending order from left to right. Therefore, the largest change resulting from a 10% decrease in pollock survival in both ecosystems is a decrease in adult pollock biomass, as might have been expected from such a perturbation. However, the decrease in pollock biomass resulting from the 10% survival reduction is uncertain in AI: the 50% intervals range from a 5-37% decrease in the AI (Fig. 1A.34, upper panel). Along with the decrease in pollock biomass predicted in this simulation is a decrease in pollock fishery catch. The next largest median effect is on juvenile pollock, which are predicted to decrease in 50% of feasible ecosystems, but the 95% interval includes zero, suggesting that the decrease is uncertain. The simulation further suggests the possibility that herring, Atka mackerel, and other miscellaneous deepwater fish might increase slightly as a result of a decrease in pollock survival; however, for all of these species groups the 95% intervals cross zero, so the direction of change is uncertain. Therefore, this analysis suggests that in the AI ecosystem during the early 1990's, pollock were most important to themselves, and to the pollock fishery.

To determine which groups were most important to pollock in each ecosystem, we conducted the inverse of the analysis presented above. In this simulation, each species group in the ecosystem had survival reduced by 10% and the system was allowed to adjust over 30 years. The strongest median effects on AI adult pollock are presented in Fig. 1A.34 (lower panel). The largest effect on adult pollock was the reduction in biomass resulting from the reduced survival of juvenile pollock, although the 95% intervals include zero change, indicating considerable uncertainty in this result. (The same caution applies to the interpretation of all of the results of this simulation as all of the 95% intervals contain zero). It is interesting, however, that reduced survival of juvenile Atka mackerel had a larger median effect on adult pollock biomass than the direct effect of reduced adult pollock survival itself (Fig. 1A.34, lower panel), and that the effect is positive. Adult Atka mackerel show the same pattern, which is likely explained by the amount of mortality caused by Atka mackerel on juvenile pollock in the AI food web model (see Fig. 1A.30, lower panels). Reduced survival of Atka mackerel adults or juveniles apparently relieves considerable mortality on juvenile pollock in this model, accounting for the increases in pollock biomass predicted (which is similar in magnitude to the increase predicted from reducing the pollock fishery catch by 10%). Although this result is uncertain, it does indicate an important interaction between two commercially important species in the AI ecosystem which might be further investigated.

Ecosystem effects on Aleutian Islands Walleye Pollock

The following ecosystem considerations are summarized in Table 1A.16.

Prey availability/abundance trends

Adult walleye pollock in the Aleutian Islands consume a variety of prey, primarily large zooplankton, copepods, and myctophids. Figure 1A.31 highlights the trophic level of pollock in relation to its prey and predators. No time series of information is available on Aleutian Islands for large zooplankton, copepod, or myctophid abundance.

Predator population trends

The abundance trend of Aleutian Islands Pacific cod is decreasing, and the trend for Aleutian Islands arrowtooth flounder is relatively stable. Northern fur seals are showing declines, and Steller sea lions have shown some slight increases. Declining trends in predator abundance could lead to possible decreases in walleye pollock mortality. The population trends of seabirds are mixed, some increases, some decreases, and others stable. Seabird population trends could affect young-of-the-year mortality.

Changes in habitat quality

The 2006 Aleutian Islands summer bottom temperatures indicated that water temperatures were slightly cooler at shallower depths than 2004, but was otherwise an average year. Bottom temperatures could possibly affect fish distribution, but there have been no directed studies, and there is no time series of data which demonstrates the effects on Aleutian Islands walleye pollock.

AI pollock fishery effects on the ecosystem

AI pollock fishery contribution to bycatch

The 2007 and 2006 AI pollock fishery were conducted in conjunction with the AICASS, Pacific Ocean perch (POP) was the most substantial bycatch species and made up 3% of the catch in 2006 and 11% in 2007. The AI pollock fishery opening in 2005 was limited to only four hauls, within these four hauls the bycatch level of POP was very high (~50%). Besides the lack of commercially harvestable levels of pollock, the high levels of POP bycatch convinced fishers to discontinue the fishery in 2005. Prior to 1998, levels of bycatch in the pollock fishery of prohibited species, forage, HAPC biota, marine mammals and birds, and other sensitive non-target species was very low compared to other fisheries in the region.

Concentration of AI pollock catches in time and space

Since no EFP is propose for 2008 there is expected to only be a very limited fishery in 2008. The State of Alaska may continue to manage a 3,000 t AI pollock fishery in state waters, but participation is limited to vessels under 58 ft. There are very few vessels less than 58' that can safely equip themselves for a deep water pollock fisher and therefore catch is expected to be much less than 3,000 t even if the state opens this fishery. The impacts of this fishery due to temporal and spatial concentration are not expected be substantial due to the relatively low fishing mortality expected.

AI pollock fishery effects on amount of large size walleye pollock

The AI pollock fishery in the Aleutian Islands was closed between 1999 and 2005. There was only a very limited fishery in 2005 (< 200t), 2006 (932 t), and 2007 (1,300 t). Year to year differences observed in the previous eight years can not be attributed to the fishery and must be attributed to natural fluctuations in recruitment. Fishers have indicated that the larger pollock in the Aleutian Islands will be targeted. But the low level of fishing mortality is not expected to greatly affect the size distribution of pollock in the AI.

AI pollock fishery contribution to discards and offal production

The 2007 Aleutian Islands pollock fishery, if pursued, is expected to be conducted by catcher vessels delivering unsorted catch to the Adak Fisheries LLC processing plant, and therefore very little discard or offal production is expected from this fishery.

AI Pollock fishery effects on AI pollock age-at-maturity and fecundity

The effects of the fishery on the age-at-maturity and fecundity of AI pollock are unknown. No studies on AI pollock age-at-maturity or fecundity have been conducted. Studies are needed to determine if there have been changes over time and whether changes could be attributed to the fishery.

Data gaps and research priorities

Very little is known about the AI pollock stock structure and their relation to Western Bering Sea, Eastern Bering Sea, Gulf of Alaska, Bogoslof and Central Bering Sea pollock. Genetic work on the relationship of NRA pollock to other stocks in the North Pacific is essential for further assessment work. Tissue samples were collected during the 2006 and 2007 AICASS for this analysis but genetic analysis of these samples are waiting on funding. In addition, studies on the migration of pollock in the North Pacific should be explored in order to obtain an understanding of how the stocks relate spatially and temporally and how neighboring fisheries affect local abundances. Time series data sets on prey species abundance in the Aleutian Islands would be useful for a more clear understanding of ecosystem affects. Studies to determine the impacts of environmental indicators such as temperature regime on AI Aleutian pollock are needed. Currently, we rely on studies from the eastern Bering Sea for our estimates of life history parameters (e.g. maturity-at-age, fecundity, and natural mortality) for the NRA pollock. Studies specific to the NRA to determine whether there are any differences from the eastern Bering Sea stock and whether there have been any changes in life history parameters over time would be informative.

Summary

Model 2B Parameters

Natural Morality:	M = 0.218
Initial Biomass (1978):	B_0 = 288,380 t

2008

Maximum permissible ABC:	Tier 3a Model 2B $F_{40\%}$ = 0.196	yield = 28,160 t
	Tier 5 (M=0.218)	yield = 15,530 t
	Tier 5 (M = 0.3)	yield = 21,370 t
Overfishing (OFL):	Tier 3a Model 2B $F_{35\%}$ = 0.38	yield = 34,040 t
	Tier 5(M = 0.218)	yield = 20,710 t
	Tier 5 (M=0.3)	yield = 28,500 t

2009

Maximum permissible ABC:	Tier 3a Model 2B $F_{40\%}$ = 0.196	yield = 22,670 t
	Tier 5 (M=0.218)	yield = 15,530 t
	Tier 5 (M = 0.3)	yield = 21,370 t

Overfishing (OFL):	Tier 3a Model 2B $F_{35\%}$ = 0.38	yield = 26,060 t
	Tier 5(M = 0.218)	yield = 20,710 t
	Tier 5 (M=0.3)	yield = 28,500 t

Model 2B Equilibrium female spawning biomass

$B_{100\%}$	=	128,620 t
$B_{40\%}$	=	51,450 t
$B_{35\%}$	=	45,020 t

Model 2B Projected 2008 biomass

Age 3+ biomass	= 197,280 t
Female spawning biomass	= 82,250 t

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Tables

Table 1A.1. Time series of ABC, TAC, and total catch for Aleutian Islands Region walleye pollock fisheries 1991-2007. Units are in metric tons. Note: There was no OFL level set in 1991 and the 1993 harvest specifications were not available

YEAR	ABC	TAC	OFL	CATCH	CATCH/TAC
1991	101,460	72,250	NA	98,604	136%
1992	51,600	47,730	62,400	52,352	110%
1993				57,132	
1994	56,600	56,600	60,400	58,659	104%
1995	56,600	56,600	60,400	64,925	115%
1996	35,600	35,600	47,000	29,062	82%
1997	28,000	28,000	38,000	25,940	93%
1998	23,800	23,800	31,700	23,822	100%
1999	23,800	2,000	31,700	1,010	51%
2000	23,800	2,000	31,700	1,244	62%
2001	23,800	2,000	31,700	824	41%
2002	23,800	1,000	31,700	1,156	116%
2003	39,400	1,000	52,600	1,653	165%
2004	39,400	1,000	52,600	1,150	115%
2005	29,400	19,000	39,100	1,556	8%
2006	29,400	19,000	39,100	1,736	9%
2007	44,500	19,000	54,500	*2,359	12%

* As of August 16, 2007

Table 1A.2. Estimates of walleye pollock catches from the entire Aleutian Islands Region by source, 1977-2007. Units are in metric tons.

Year	Official Foreign & JV Blend	Domestic Blend	Foreign Reported	NMFS Observer Data	Current estimates
1977	7,367		7,827	5	7,367
1978	6,283		6,283	234	6,283
1979	9,446		9,505	58	9,446
1980	58,157		58,477	883	58,157
1981	55,517		57,056	2,679	55,517
1982	57,753		62,624	11,847	57,753
1983	59,021		44,544	12,429	59,021
1984	77,595		67,103	48,538	77,595
1985	58,147		48,733	43,844	58,147
1986	45,439		14,392	29,464	45,439
1987	28,471			17,944	28,471
1988	41,203			21,987	41,203
1989	10,569			5,316	10,569
1990		79,025		51,137	79,025
1991		98,604		20,493	98,604
1992		52,352		20,853	52,352
1993		57,132		22,804	57,132
1994		58,659		37,707	58,659
1995		64,925		18,023	64,925
1996		29,062		5,982	29,062
1997		25,940		5,580	25,940
1998		23,822		1,882	23,822
1999		1,010		24	1,010
2000		1,244		75	1,244
2001		824		88	824
2002		1,156		144	1,156
2003		1,653			1,653
2004		1,150			1,150
2005		1,610			1,610
2006		1,736			1,736
2007		2,349			2,349

Table 1A.3. Estimated walleye pollock catch discarded and retained for the Aleutian Islands Region based on NMFS blend data, 1991-2007.

Year	Catch Retained	Discard	Total	Discard Percentage
1990	69,682	9,343	79,025	12%
1991	93,059	5,441	98,500	6%
1992	49,375	2,986	52,361	6%
1993	55,399	1,740	57,138	3%
1994	57,308	1,373	58,681	2%
1995	63,545	1,380	64,925	2%
1996	28,067	994	29,062	3%
1997	25,323	617	25,940	2%
1998	23,657	164	23,822	1%
1999	361	446	807	55%
2000	455	790	1,244	64%
2001	445	380	824	46%
2002	398	758	1,156	66%
2003	1184	468	1,653	28%
2004	871	278	1,150	24%
2005	200	1,410	1,610	88%
2006	897	839	1,736	48%
2007	1,429	930	2,359	39%

Table 1A.4. Estimates of Aleutian Islands Region walleye pollock catch by the three management sub-areas. Foreign reported data were used from 1977-1984, from 1985-1998 observer data were used to partition catches among the areas. Units are in metric tons.

Year	East (541)	Central (542)	West (543)	Total
1977	4,402	0	2,965	7,367
1978	5,267	712	305	6,283
1979	1,488	1,756	6,203	9,446
1980	28,284	7,097	22,775	58,157
1981	43,461	10,074	1,982	55,517
1982	54,173	1,205	2,376	57,753
1983	56,577	1,250	1,194	59,021
1984	64,172	5,760	7,663	77,595
1985	19,885	38,163	100	58,147
1986	38,361	7,078	0	45,439
1987	28,086	386	0	28,471
1988	40,685	517	0	41,203
1989	10,569	0	0	10,569
1990	69,170	9,425	430	79,025
1991	98,032	561	11	98,604
1992	52,140	206	6	52,352
1993	54,512	2,536	83	57,132
1994	58,091	554	15	58,659
1995	28,109	36,714	102	64,925
1996	9,226	19,574	261	29,062
1997	8,110	16,799	1,031	25,940
1998	1,837	3,858	18,127	23,822

Table 1A.5. Estimates of pollock catch (metric tons) by new area definitions. "NRA" stands for Near, Rat, and Andreanof island groups, "NRA w/o E" signifies the NRA region without the area east of 174°W, "Basin" represents the northern portions of areas 541 and 542. See Fig. 1A.3 for locations on a map. (*Note: 1977-1984 area assignments are based on foreign reported data, 1985- 2007 are based on observer data).*

Year	NRA	NRA w/o E	Basin	Basin + E
1977	7,367	2,965	0	4,402
1978	6,283	1,016	0	5,267
1979	9,446	7,959	0	1,488
1980	58,157	29,873	0	28,284
1981	31,258	14,811	24,259	40,706
1982	50,322	3,149	7,863	54,605
1983	44,442	1,669	15,354	57,352
1984	42,901	9,171	39,140	68,424
1985	47,070	870	48,472	57,278
1986	23,810	704	28,003	44,735
1987	26,257	2,720	2,251	25,752
1988	36,864	574	4,339	40,628
1989	10,569	0	0	10,569
1990	79,025	10,477	0	68,548
1991	98,604	561	230	98,043
1992	52,352	8,519	29,455	43,833
1993	57,132	16,162	22,404	40,970
1994	58,659	5,965	26,288	52,694
1995	64,925	58,203	3,015	6,723
1996	29,062	23,187	899	5,875
1997	25,940	25,774	0	166
1998	23,822	23,335	67	486
1999	1,010	631	0	378
2000	1,244	891	0	354
2001	824	575	0	249
2002	1,156	351	1	805
2003	1,653	1,430	0	222
2004	1,150	962	0	188
2005	1,610	1,330	0	280
2006	1,736	1,657	0	79
2007	2,359		0	

Table 1A.6. Sampling levels in Aleutian Islands Region sub-regions based on foreign, J.V., and domestic walleye pollock observer data 1978 – 1998.

	NRA West of 174° Longitude			NRA East of 174° Longitude			Aleutian Islands Area Basin		
Year	Fish Measured	Hauls Sampled	Vessels Sampled	Fish Measured	Hauls Sampled	Vessels Sampled	Fish Measured	Hauls Sampled	Vessels Sampled
1978	1,503	64	4	4,831	135	11	0	0	0
1979	1,317	16	4	977	33	6	0	0	0
1980	2,154	53	4	4,753	119	10	0	0	0
1981	4,782	37	7	6,617	96	14	1,913	15	3
1982	7,713	102	13	29,549	331	30	11,151	84	7
1983	2,977	35	12	24,793	242	27	20,744	174	21
1984	10,844	111	22	46,037	541	49	157,388	1,223	81
1985	780	9	2	33,471	259	37	68,923	460	58
1986	0	0	0	22,939	195	18	39,875	268	48
1987	4,045	26	5	43,093	352	29	2,665	26	8
1988	378	3	2	28,423	249	24	4,528	37	14
1989	0	0	0	7,424	57	8	0	0	0
1990	12,303	131	14	55,837	587	47	55	1	1
1991	0	1	1	26,035	211	32	24,025	194	26
1992	7,405	59	15	18,771	178	50	20,769	179	27
1993	13,471	130	15	13,264	137	34	22,022	185	30
1994	5,025	47	18	29,805	305	64	5,314	56	16
1995	29,070	324	34	2,963	212	31	1,922	19	7
1996	15,307	160	35	3,462	179	41	0	0	0
1997	17,239	189	33	64	122	26	77	1	1
1998	10,439	122	15	148	107	12	0	0	0
Total	146,752	1,619	255	403,256	4,647	600	381,371	2,922	348

Table 1A.7. NRA pollock fishery average weight-at-age in kilograms used in reference model. Shaded cells had missing observations and were filled with their mean values

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1978	0.3318	0.3933	0.7603	0.6877	0.8097	0.9151	0.9065	0.9722	0.9281	1.0613	1.1674	1.187	1.6149	1.0729
1979	0.2314	0.3476	0.5293	0.7306	0.6727	0.825	0.9435	0.9532	1.0381	1.1638	1.0598	1.5186	1.5788	1.0206
1980	0.2392	0.5526	0.7651	0.8412	0.8629	0.9129	1.0002	1.089	1.0628	1.0204	1.1568	1.1019	0.8521	1.5242
1981	0.3392	0.4778	0.5521	0.7286	0.7637	0.7817	0.8096	0.8953	0.9021	0.8598	1.0199	1.0259	0.8929	0.9079
1982	0.3392	0.4179	0.5414	0.6436	0.7838	0.822	0.8417	0.8921	0.9842	1.0011	0.9575	0.9546	0.9058	0.966
1983	0.3392	0.4736	0.6609	0.7333	0.7796	0.7954	0.9264	0.9574	1.0146	0.9024	1.1892	1.1496	0.974	1.14
1984	0.426	0.4459	0.6609	0.7419	0.8099	0.8721	0.968	0.9963	1.2704	1.6431	1.1351	1.2212	1.1943	1.14
1985	0.4675	0.5656	0.6705	0.6896	0.8028	0.8536	0.8567	1.0909	1.233	1.5996	1.6644	1.1496	1.6448	1.14
1986	0.3392	0.5114	0.6019	0.7472	0.8266	0.8698	0.9506	0.9266	1.0137	0.9428	1.0702	0.8963	1.1943	1.14
1987	0.3392	0.4736	0.6852	0.7562	0.8335	0.8504	0.8715	0.9809	1.0725	0.9915	1.3379	1.1546	1.0065	1.0935
1988	0.3392	0.4736	0.6609	0.8013	0.7905	0.8208	0.9279	0.8883	0.9839	0.8933	0.7843	0.7223	0.8976	1.0621
1989	0.3392	0.4736	0.6609	0.7536	0.851	0.926	0.9927	1.0611	1.1106	1.1501	1.1892	1.1496	1.1943	1.14
1990	0.3392	0.4778	0.5521	0.7286	0.7637	0.7817	0.8096	0.8953	0.9021	0.8598	1.0199	1.0259	0.8929	0.9079
1991	0.3392	0.4736	0.6668	0.6551	0.7989	0.962	1.0755	1.1731	1.0994	1.2177	1.1573	1.0955	1.2898	1.0856
1992	0.3392	0.4736	0.6401	0.7418	0.7254	0.797	0.9356	1.2457	1.0267	1.0034	1.2501	1.1451	1.0514	1.0976
1993	0.3392	0.4736	0.8862	0.8237	1.0335	1.0315	1.1399	1.0808	1.1638	1.1905	1.2027	1.3256	1.1373	1.1352
1994	0.3392	0.4736	0.6373	0.8437	0.9743	1.1361	1.14	1.1216	1.1907	1.2437	1.2659	1.0591	1.09	1.1517
1995	0.3392	0.5512	0.8471	0.7536	1.1264	1.3303	1.3972	1.3551	1.4333	1.4197	1.501	1.4466	1.6582	1.3206
1996	0.3392	0.5391	0.4753	0.9301	1.0287	1.1796	1.2751	1.3945	1.4682	1.3548	1.3777	1.3619	1.4562	1.3013
1997	0.3392	0.4736	0.6609	0.7536	0.851	0.926	0.9927	1.0611	1.1106	1.1501	1.1892	1.1496	1.1943	1.14
1998	0.3392	0.403	0.7631	0.7398	0.9826	1.0575	1.085	1.2532	1.3137	1.4826	1.2785	1.3012	1.3597	1.4522
1999	0.3392	0.4736	0.6609	0.7536	0.851	0.926	0.9927	1.0611	1.1106	1.1501	1.1892	1.1496	1.1943	1.14
2000	0.3392	0.4736	0.6609	0.7536	0.851	0.926	0.9927	1.0611	1.1106	1.1501	1.1892	1.1496	1.1943	1.14
2001	0.3392	0.4736	0.6609	0.7536	0.851	0.926	0.9927	1.0611	1.1106	1.1501	1.1892	1.1496	1.1943	1.14
2002	0.3392	0.4736	0.6609	0.7536	0.851	0.926	0.9927	1.0611	1.1106	1.1501	1.1892	1.1496	1.1943	1.14
2003	0.3318	0.3933	0.7603	0.6877	0.8097	0.9151	0.9065	0.9722	0.9281	1.0613	1.1674	1.187	1.6149	1.0729
2004	0.3318	0.3933	0.7603	0.6877	0.8097	0.9151	0.9065	0.9722	0.9281	1.0613	1.1674	1.187	1.6149	1.0729
2005	0.3318	0.3933	0.7603	0.6877	0.8097	0.9151	0.9065	0.9722	0.9281	1.0613	1.1674	1.187	1.6149	1.0729
2006	0.3318	0.3933	0.7603	0.6877	0.8097	0.9151	0.9065	0.9722	0.9281	1.0613	1.1674	1.187	1.6149	1.0729
2007	0.3318	0.3933	0.7603	0.6877	0.8097	0.9151	0.9065	0.9722	0.9281	1.0613	1.1674	1.187	1.6149	1.0729

Table 1A.8. Number of aged and measured fish in the NRA pollock fishery used to estimate fishery age composition. Shaded values were not used in assessment. Data for 2006 from 2006 AICASS.

	Number Aged			Number Measured		
Year	Males	Females	Total	Males	Females	Total
1978	209	322	531	490	1,013	1,503
1979	124	178	302	611	706	1,317
1980	93	167	260	971	1,183	2,154
1981	124	152	276	2,226	2,556	4,782
1982	564	640	1,204	3,655	4,058	7,713
1983	132	145	277	1,493	1,484	2,977
1984	294	312	606	5,273	5,571	10,844
1985	210	265	475	349	431	780
1986	77	113	190	0	0	0
1987	131	142	273	1,670	2,375	4,045
1988	34	33	67	188	190	378
1989	0	0	0	0	0	0
1990	46	49	95	5,209	7,094	12,303
1991	36	47	83	0	0	80
1992	110	121	231	3,755	3,650	7,405
1993	81	82	163	7,701	5,770	13,471
1994	157	151	308	2,644	2,381	5,025
1995	74	106	180	16,518	12,552	29,070
1996	95	84	179	8,933	6,374	15,307
1997	15	15	30	9,232	8,007	17,239
1998	144	170	314	5,992	4,447	10,439
1999	0	0	0	75	60	135
2000	0	1	1	70	114	184
2001	0	1	1	52	106	158
2002	0	0	0	46	61	107
2003	0	0	0	0	0	0
2004	0	0	0	153	212	365
2005	0	0	0	309	260	569
2006	74	87	161	1,315	1,630	2,945

Table 1A.9. Number of individual vessels and hauls sampled by observers in the NRA pollock fishery west of 174°W longitude, 1990-1998.

	NRA Area 541 West of 174W				NRA Area 542				NRA Area 543			
	Catcher Processor		Catcher Only		Catcher Processor		Catcher Only		Catcher Processor		Catcher Only	
Year	Vessels	Hauls	Vessels	Hauls	Vessels	Hauls	Vessels	Hauls	Vessels	Hauls	Vessels	Hauls
1990	12	50	0	0	16	132	0	0	2	4	0	0
1991	2	3	0	0	2	2	0	0	0	0	0	0
1992	18	126	0	0	4	5	0	0	0	0	0	0
1993	18	195	0	0	6	25	0	0	3	5	0	0
1994	18	76	0	0	3	6	0	0	0	0	0	0
1995	22	200	8	39	15	272	11	77	0	0	0	0
1996	5	12	7	15	25	198	10	38	0	0	0	0
1997	13	66	11	30	14	93	10	60	1	6	0	0
1998	4	6	5	16	3	24	5	19	2	97	4	24

Table 1A.10. Estimated NRA region pollock catch at age (millions). Highest mode for each year is shaded.

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1978	0.01	0.14	0.12	0.07	0.36	0.10	0.14	0.13	0.13	0.06	0.02	0.01		0.00	1.27
1979	0.01	2.18	2.22	2.02	2.43	1.73	0.65	0.63	0.37	0.03	0.22			0.05	12.53
1980	8.20	3.24	2.64	3.71	6.94	4.05	2.47	0.73	1.07	0.53	0.16	0.01	0.14	0.01	33.91
1981		5.72	3.36	2.19	1.65	2.55	2.54	1.93	1.37	0.73	0.20	0.15	0.20	0.04	22.64
1982		0.01	3.00	0.51	0.23	0.31	0.38	0.35	0.15	0.07	0.04	0.03	0.01	0.01	5.10
1983				0.74	0.44	0.17	0.11	0.24	0.23	0.05	0.04	0.01	0.00	0.00	2.04
1984	0.14	3.97		4.12	4.12	1.46	1.10	0.74	0.51	0.34	0.09	0.06	0.03	0.01	16.68
1985	0.01	0.01	0.17	0.06	0.17	0.46	0.20	0.08	0.08	0.04	0.01	0.01	0.00	0.00	1.30
1986															
1987			1.40	0.31	0.23	0.04	0.09	1.01	0.09	0.12	0.00	0.03	0.01	0.04	3.36
1988															
1989															
1990		0.95	0.26	0.96	0.78	0.78	0.93	0.17	1.10	0.34	0.56	0.28	0.13	0.21	7.45
1991															
1992			0.03	0.33	0.60	0.30	0.60	0.12	0.69	0.39	0.52	0.36	1.71	1.91	7.55
1993			0.18	0.47	1.12	1.34	0.54	1.46	0.81	0.88	0.83	0.38	0.70	4.34	13.05
1994			0.07	1.00	0.31	0.42	0.60	0.43	0.33	0.17	0.39	0.10	0.08	1.30	5.20
1995		0.22	0.38	0.00	10.22	1.19	5.10	4.84	1.42	2.36	2.08	3.82	0.77	8.32	40.71
1996		0.17	0.15	0.56	1.42	5.15	1.53	2.09	1.21	0.92	0.64	0.20	0.77	2.00	16.79
1997															
1998		0.05	0.08	5.66	1.65	1.05	0.96	1.71	1.20	1.00	2.40	1.30	1.17	1.49	19.73
2006				0.01	0.33	0.13	0.04	0.02	0.08	0.06	0.06	0.05	0.12	0.12	1.02

Table 1A.11. Pollock biomass estimates from the Aleutian Islands Groundfish Survey, 1980-2006.

	Aleutian Islands Region				
	NRA West (174W-170E)	NRA East (170W-174W)	NRA total	Unalaska-Umnak area (~165W-170W)	Combined
1980			243,695	56,732	300,427
1983			495,775	282,648	778,423
1986			439,461	102,379	541,840
1991	83,337	53,865	137,202	51,644	188,846
1994	47,623	29,879	77,502	39,696	117,199
1997	57,577	39,935	97,512	65,400	158,912
2000	76,613	28,985	105,598	22,462	128,060
2002	121,915	53,368	175,283	181,334	356,617
2004	19,201	111,250	130,451	235,658	366,110
2006	25,471	69,522	94,993	18,006	112,999

Table 1A.12. Results of the 2002 Aleutian Islands echo integration-trawl survey conducted by the R/V Kaiyo Maru.

	Leg 2-1	Leg 2-2	Leg 2-3	Leg 2-4
Area (km^2)	27,902	10,433	4,045	1,413
Density (t/km^2)	2.18	1.82	2.46	1.79
Population (10^6)	37	12	6	2
Biomass (10^3 t)	61	19	10	3
CV	0.31	0.33	0.21	0.76

Table 1A.13. Results from the 2006 Aleutian Islands Cooperative Acoustic Survey.

Survey	Area (n.mi.^{2})	Deadzone (Y/N)	Biomass (t)	Relative Precision (E_i)	High Biom. (t)	Low Biom. (t)	Density (t / n.mi.^{2})
2	180	N	8233.8	8.67%	9632.5	6835.1	45.7
2	180	Y	8809.9	8.04%	10198.4	7421.4	48.9
2	72	N	6484.5	12.29%	8046.1	4922.9	90.1
2	72	Y	6706.6	14.32%	8589.2	4824.0	93.1
4	180	N	6600.4	7.96%	7630.1	5570.7	36.7
4	180	Y	7980.2	7.87%	9210.6	6749.8	44.3
4	72	N	5246.4	12.31%	6512.6	3980.2	72.9
4	72	Y	6149.8	11.89%	7582.5	4717.1	85.4
5	9	N	890.8	5.29%	983.2	798.4	99.0
5	9	Y	1036.6	4.75%	1133.1	940.1	115.2
6	72	N	3015.0	6.64%	3407.4	2622.6	41.9
6	72	Y	3458.5	6.44%	3894.9	3022.1	48.0
7	72	N	1159.0	6.83%	1314.2	1003.8	16.1
7	72	Y	2179.7	5.05%	2395.4	1964.0	30.3
8	180	N	2313.6	14.51%	2971.6	1655.6	12.9
8	180	Y	2845.2	14.24%	3639.0	2051.4	15.8
8	72	N	559.2	14.32%	716.1	402.3	7.8
8	72	Y	677.0	12.96%	848.9	505.1	9.4

Table 1A.14. Estimated instantaneous natural mortality rates (M) by age from Wespestad and Terry (1984).

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
M	0.85	0.45	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6

Table 1A.15. Estimated von Bertalanffy growth curve parameters and length-weight regression parameters for walleye pollock sampled during the U.S.-Japan 1980, 1983, and 1986 groundfish surveys and the 1991, 1994, 1997, 2000, 2002, and 2004 RACE groundfish surveys.

	L_{inf}	K	t_0	A	b
1980	51.92	0.414	-0.525	0.0132	2.858
1983	53.26	0.383	0.002	0.0178	2.768
1986	51.02	0.443	-0.084	0.0142	2.831
1991	54.55	0.392	-0.361	0.0104	2.912
1994	61.58	0.330	-0.102	0.0069	3.022
1997	61.41	0.286	-0.397	0.0081	2.983
2000	62.58	0.306	-0.048	0.0064	3.019
2002	64.36	0.289	-0.127	0.0066	3.018
2004	61.76	0.332	-0.189	0.0065	3.022

Table 1A.16. Average weight-at-age for Aleutian Islands pollock as estimated from NMFS summer bottom trawl survey estimates. Values between survey years (shaded) were set to the mean of the nearest two surveys (or single year for 1978-79, 2003-04).

							Age							
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1978	0.31	0.49	0.65	0.76	0.85	0.91	0.95	0.98	0.99	1.01	1.01	1.02	1.02	1.03
1979	0.31	0.49	0.65	0.76	0.85	0.91	0.95	0.98	0.99	1.01	1.01	1.02	1.02	1.03
1980	0.31	0.49	0.65	0.76	0.85	0.91	0.95	0.98	0.99	1.01	1.01	1.02	1.02	1.03
1981	0.25	0.43	0.60	0.73	0.83	0.90	0.95	0.98	1.01	1.02	1.03	1.04	1.05	1.05
1982	0.25	0.43	0.60	0.73	0.83	0.90	0.95	0.98	1.01	1.02	1.03	1.04	1.05	1.05
1983	0.19	0.37	0.55	0.69	0.80	0.89	0.95	0.99	1.02	1.04	1.05	1.06	1.07	1.07
1984	0.21	0.40	0.57	0.71	0.82	0.90	0.95	0.99	1.02	1.04	1.05	1.06	1.07	1.07
1985	0.21	0.40	0.57	0.71	0.82	0.90	0.95	0.99	1.02	1.04	1.05	1.06	1.07	1.07
1986	0.24	0.42	0.59	0.73	0.83	0.90	0.96	0.99	1.02	1.04	1.05	1.06	1.06	1.06
1987	0.23	0.46	0.67	0.77	0.89	0.97	1.02	1.07	1.12	1.14	1.09	1.11	1.11	1.09
1988	0.23	0.46	0.67	0.77	0.89	0.97	1.02	1.07	1.12	1.14	1.09	1.11	1.11	1.09
1989	0.23	0.46	0.67	0.77	0.89	0.97	1.02	1.07	1.12	1.14	1.09	1.11	1.11	1.09
1990	0.23	0.46	0.67	0.77	0.89	0.97	1.02	1.07	1.12	1.14	1.09	1.11	1.11	1.09
1991	0.22	0.51	0.69	0.79	1.01	1.15	1.26	1.21	1.27	1.21	1.16	1.12	1.16	1.10
1992	0.21	0.51	0.78	0.89	1.08	1.22	1.25	1.33	1.36	1.32	1.35	1.33	1.35	1.22
1993	0.21	0.51	0.78	0.89	1.08	1.22	1.25	1.33	1.36	1.32	1.35	1.33	1.35	1.22
1994	0.20	0.52	0.87	1.00	1.14	1.29	1.24	1.45	1.44	1.43	1.54	1.54	1.54	1.35
1995	0.22	0.48	0.82	0.97	1.07	1.24	1.26	1.38	1.44	1.45	1.53	1.52	1.57	1.47
1996	0.22	0.48	0.82	0.97	1.07	1.24	1.26	1.38	1.44	1.45	1.53	1.52	1.57	1.47
1997	0.25	0.43	0.78	0.95	1.00	1.19	1.29	1.31	1.44	1.47	1.52	1.51	1.60	1.60
1998	0.21	0.47	0.77	0.92	0.95	1.17	1.28	1.31	1.43	1.50	1.62	1.59	1.53	1.65
1999	0.21	0.47	0.77	0.92	0.95	1.17	1.28	1.31	1.43	1.50	1.62	1.59	1.53	1.65
2000	0.17	0.51	0.77	0.89	0.90	1.15	1.26	1.32	1.41	1.52	1.71	1.67	1.47	1.70
2001	0.19	0.49	0.74	1.02	1.03	1.23	1.29	1.43	1.53	1.56	1.74	1.68	1.58	1.67
2002	0.21	0.47	0.70	1.15	1.16	1.32	1.32	1.53	1.65	1.61	1.76	1.69	1.68	1.64
2003	0.21	0.47	0.70	1.15	1.16	1.32	1.32	1.53	1.65	1.61	1.76	1.69	1.68	1.64
2004	0.23	0.49	0.79	0.91	1.02	1.25	1.22	1.50	1.53	1.70	1.63	1.64	1.55	0.87
2005	0.23	0.49	0.79	0.91	1.02	1.25	1.22	1.50	1.53	1.70	1.63	1.64	1.55	0.93
2006	0.17	0.49	0.67	0.95	1.20	1.29	1.40	1.57	1.93	2.05	1.96	2.03	1.94	1.97
2007	0.17	0.49	0.67	0.95	1.20	1.29	1.40	1.57	1.93	2.05	1.96	2.03	1.94	1.97

Table 1A.17. Average weight-at-age for Aleutian Islands pollock as estimated from fishery data.

	Age													
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1978	0.33	0.39	0.76	0.69	0.81	0.92	0.91	0.97	0.93	1.06	1.17	1.19	1.61	1.07
1979	0.23	0.35	0.53	0.73	0.67	0.83	0.94	0.95	1.04	1.16	1.06	1.52	1.58	1.02
1980	0.24	0.55	0.77	0.84	0.86	0.91	1.00	1.09	1.06	1.02	1.16	1.10	0.85	1.52
1981	0.34	0.48	0.55	0.73	0.76	0.78	0.81	0.90	0.90	0.86	1.02	1.03	0.89	0.91
1982	0.34	0.42	0.54	0.64	0.78	0.82	0.84	0.89	0.98	1.00	0.96	0.95	0.91	0.97
1983	0.34	0.47	0.66	0.73	0.78	0.80	0.93	0.96	1.01	0.90	1.19	1.15	0.97	1.14
1984	0.43	0.45	0.66	0.74	0.81	0.87	0.97	1.00	1.27	1.64	1.14	1.22	1.19	1.14
1985	0.47	0.57	0.67	0.69	0.80	0.85	0.86	1.09	1.23	1.60	1.66	1.15	1.64	1.14
1986	0.34	0.51	0.60	0.75	0.83	0.87	0.95	0.93	1.01	0.94	1.07	0.90	1.19	1.14
1987	0.34	0.47	0.69	0.76	0.83	0.85	0.87	0.98	1.07	0.99	1.34	1.15	1.01	1.09
1988	0.34	0.47	0.66	0.80	0.79	0.82	0.93	0.89	0.98	0.89	0.78	0.72	0.90	1.06
1989	0.34	0.47	0.66	0.75	0.85	0.93	0.99	1.06	1.11	1.15	1.19	1.15	1.19	1.14
1990	0.34	0.48	0.55	0.73	0.76	0.78	0.81	0.90	0.90	0.86	1.02	1.03	0.89	0.91
1991	0.34	0.47	0.67	0.66	0.80	0.96	1.08	1.17	1.10	1.22	1.16	1.10	1.29	1.09
1992	0.34	0.47	0.64	0.74	0.73	0.80	0.94	1.25	1.03	1.00	1.25	1.15	1.05	1.10
1993	0.34	0.47	0.89	0.82	1.03	1.03	1.14	1.08	1.16	1.19	1.20	1.33	1.14	1.14
1994	0.34	0.47	0.64	0.84	0.97	1.14	1.14	1.12	1.19	1.24	1.27	1.06	1.09	1.15
1995	0.34	0.55	0.85	0.75	1.13	1.33	1.40	1.36	1.43	1.42	1.50	1.45	1.66	1.32
1996	0.34	0.54	0.48	0.93	1.03	1.18	1.28	1.39	1.47	1.35	1.38	1.36	1.46	1.30
1997	0.34	0.47	0.66	0.75	0.85	0.93	0.99	1.06	1.11	1.15	1.19	1.15	1.19	1.14
1998	0.34	0.40	0.76	0.74	0.98	1.06	1.09	1.25	1.31	1.48	1.28	1.30	1.36	1.45
1999	0.34	0.47	0.66	0.75	0.85	0.93	0.99	1.06	1.11	1.15	1.19	1.15	1.19	1.14
2000	0.34	0.47	0.66	0.75	0.85	0.93	0.99	1.06	1.11	1.15	1.19	1.15	1.19	1.14
2001	0.34	0.47	0.66	0.75	0.85	0.93	0.99	1.06	1.11	1.15	1.19	1.15	1.19	1.14
2002	0.34	0.47	0.66	0.75	0.85	0.93	0.99	1.06	1.11	1.15	1.19	1.15	1.19	1.14
2003	0.33	0.39	0.76	0.69	0.81	0.92	0.91	0.97	0.93	1.06	1.17	1.19	1.61	1.07
2004	0.33	0.39	0.76	0.69	0.81	0.92	0.91	0.97	0.93	1.06	1.17	1.19	1.61	1.07
2005	0.33	0.39	0.76	0.69	0.81	0.92	0.91	0.97	0.93	1.06	1.17	1.19	1.61	1.07
2006	0.33	0.39	0.76	0.69	0.81	0.92	0.91	0.97	0.93	1.06	1.17	1.19	1.61	1.07

Table 1A.18. Percentage mature females at age from Wespestad and Terry (1984).

Age	1	2	3	4	5	6	7	8	9	10	11	12	13-16
Percent	0.0	0.8	28.9	64.1	84.2	90.1	94.7	96.3	97.0	97.8	98.4	99.0	100.0

Table 1A.19. Comparisons of fits for the evaluations of Aleutian Islands pollock Model 1 and Model 2.

	Model 1	Model 2A	Model 2B	Model 2C
Number of Parameters	195	279	280	280
Survey catchability	1.00	1.00	1.00	1.00
Fishery Average Effective N	41	44	44	43
Survey Average Effective N	144	212	211	209
RMSE Survey	0.762	0.340	0.337	0.323
-log Likelihoods				
Survey index	29.51	8.61	8.73	8.50
Fishery age comp	0.00	0.00	0.00	0.00
Survey age comp	79.43	72.25	72.40	73.82
Sub total	29.15	21.11	21.12	21.01
-log Penalties				
Recruitment	-4.62	-14.67	-14.74	-13.53
Selectivity constraint	15.93	17.14	16.54	17.56
Prior	0.11	0.01	0.09	0.09
Total	154.39	113.18	112.98	116.14

Table 1A.20. Key results for the evaluations of Aleutian Islands pollock Model 1 and Model 2.

	Model 1	Model 2A	Model 2B	Model 2C
Model conditions				
Survey catchability	1.00	1.00	1.00	1.00
Natural mortality	0.20	0.20	0.22	0.22
Fishing mortalities				
Max F 1978-2007	1.051	0.712	0.716	0.725
F 2007	0.055	0.023	0.023	0.021
Stock abundance				
Initial Biomass (1978; thousands of tons)	203.27	267	288.38	296.00
CV	11%	10%	19%	17%
2007 total biomass (thousands of tons)	88.87	203	219.39	241.92
CV	17%	18%	21%	19%
2008 Age 3+ biomass (thousands of tons)	82	192	213	230
1978 year class (at age 2)	88.87	203	219.39	241.92
CV	17%	18%	21%	19%
Recruitment Variability	0.62	0.42	0.42	0.39
Specified Sigma R	0.60	0.60	0.60	0.60
Steepness (h)	0.61	0.72	0.71	0.71
Projected catch (unadjusted)				
F50% 2008 catch	8.51	22.1	26.21	28.39
CV	18%	20%	29%	28%
F40% 2008 catch	12.80	33.4	39.36	42.72
CV	18%	20%	29%	28%
F35% 2008 catch	15.74	40.89	48.04	52.20
CV	19%	20%	29%	28%

Table 1A.21. Model 2B estimates of pollock biomass with approximate lower (LCI) and upper (UCI) 95% confidence bounds for age 2+ biomass. Also included are the age 3+ biomass and female spawning stock biomass (SSB) estimates.

M 2B Year	Total Biomass (age 2+)	LCI	UCI	Biomass Age 3+	Female SSB
1978	288,380	186,132	390,628	216,724	103,783
1979	296,010	193,282	398,738	200,997	108,207
1980	337,240	212,606	461,874	243,612	112,353
1981	335,750	196,718	474,782	264,867	114,264
1982	337,970	192,488	483,452	244,261	110,121
1983	349,040	203,552	494,528	261,318	109,228
1984	353,460	213,936	492,984	268,884	124,377
1985	344,420	213,386	475,454	267,237	137,684
1986	344,140	223,280	465,000	253,329	139,895
1987	338,740	229,938	447,542	254,099	137,377
1988	333,480	235,024	431,936	231,431	137,854
1989	331,920	242,770	421,070	253,633	137,146
1990	330,690	249,898	411,482	222,053	134,484
1991	325,990	248,186	403,794	238,078	132,596
1992	332,730	259,118	406,342	252,979	130,822
1993	322,450	254,204	390,696	290,683	124,985
1994	301,120	237,910	364,330	252,651	126,732
1995	291,530	232,326	350,734	282,261	125,738
1996	225,690	169,052	282,328	206,400	120,801
1997	202,520	146,232	258,808	157,096	111,708
1998	173,680	115,710	231,650	146,773	87,038
1999	152,910	93,510	212,310	123,179	76,203
2000	162,100	99,906	224,294	125,963	63,241
2001	173,490	106,510	240,470	132,788	57,087
2002	194,850	117,164	272,536	145,491	61,214
2003	209,430	124,832	294,028	173,515	64,389
2004	216,120	128,030	304,210	173,360	68,444
2005	218,980	129,270	308,690	162,142	75,697
2006	218,400	128,882	307,918	160,830	83,268

Table 1A.22. Results from MCMC simulations with 1 million iterations sampled every 200th iteration for reference Model 2B.

Parameter	Mode	Mean	CV
Natural Mortality	0.218	0.235	10%
Steepness	0.714	0.68	25%
Depletion	0.76	0.76	19%
2008 Total Biomass	202.15	245.24	21%
$F_{35\%}$	0.59	0.74	32%
$F_{40\%}$	0.45	0.56	31%
$F_{50\%}$	0.38	0.33	29%

Table 1A.23. Estimates of full-selection fishing mortality and exploitation rates for pollock based on the reference model (Model 2B).

Year	F^a	Catch/Biomass Rate[b]
1978	0.008	0.005
1979	0.067	0.040
1980	0.225	0.123
1981	0.134	0.056
1982	0.024	0.013
1983	0.011	0.006
1984	0.059	0.034
1985	0.005	0.003
1986	0.004	0.003
1987	0.017	0.011
1988	0.004	0.002
1989	0.000	0.000
1990	0.087	0.047
1991	0.006	0.002
1992	0.095	0.034
1993	0.181	0.056
1994	0.069	0.024
1995	0.716	0.206
1996	0.372	0.112
1997	0.680	0.164
1998	0.680	0.159
1999	0.020	0.005
2000	0.025	0.007
2001	0.015	0.004
2002	0.008	0.002
2003	0.032	0.008
2004	0.034	0.009
2005	0.031	0.010
2006	0.033	0.011
2007	0.049	0.016

[a] Full selection fishing mortality rates.
[b] Catch/biomass rate is the ratio of catch to beginning year age 3+ biomass.

Table 1A.24. Estimated pollock numbers at age in millions, 1978-2007 for reference Model 2B.

Model 2B	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	% of 15+
1978	67	59	53	40	37	17	16	12	10	8	5	4	4	19	349	5.30%
1979	88	54	47	42	32	29	14	12	10	8	6	4	4	18	368	4.81%
1980	302	70	42	37	32	24	22	10	9	7	6	5	3	17	588	2.81%
1981	68	238	54	31	26	21	16	14	7	6	5	4	3	14	508	2.84%
1982	45	55	187	40	23	19	15	11	10	5	4	4	3	14	434	3.12%
1983	78	36	44	148	32	18	15	12	9	8	4	4	3	13	423	3.17%
1984	78	63	29	35	118	25	14	12	10	7	6	3	3	13	415	3.16%
1985	78	62	50	22	27	91	20	11	9	7	5	5	2	12	403	3.08%
1986	72	63	50	40	18	22	73	16	9	7	6	4	4	12	394	2.99%
1987	55	58	51	40	32	14	17	58	12	7	6	5	3	13	372	3.37%
1988	85	45	46	40	32	25	11	14	46	10	5	5	4	13	381	3.32%
1989	78	69	36	37	32	26	20	9	11	37	8	4	4	13	384	3.42%
1990	70	63	55	29	30	26	21	16	7	9	30	6	4	13	378	3.57%
1991	134	56	50	43	22	23	20	15	12	5	7	22	5	13	426	2.99%
1992	66	108	45	40	35	18	18	16	12	10	4	5	18	14	408	3.43%
1993	51	53	86	36	31	27	14	14	12	9	7	3	4	23	371	6.25%
1994	57	41	42	68	28	24	20	10	10	9	7	5	2	18	341	5.28%
1995	58	45	33	34	54	22	19	16	8	8	7	5	4	15	327	4.62%
1996	42	46	36	25	24	36	13	11	9	5	4	3	2	7	263	2.59%
1997	50	33	37	28	19	17	25	9	8	6	3	3	2	5	244	1.93%
1998	54	40	26	28	20	13	11	15	6	4	3	1	1	2	227	1.06%
1999	37	43	31	20	20	13	8	7	9	3	3	2	1	1	200	0.64%
2000	53	30	35	25	16	16	11	6	5	8	3	2	1	1	213	0.67%
2001	68	43	24	28	20	13	13	9	5	4	6	2	2	2	238	0.89%
2002	108	54	34	19	22	16	10	10	7	4	3	5	2	3	299	0.98%
2003	42	87	44	28	15	18	13	8	8	5	3	3	4	4	283	1.29%
2004	36	34	70	35	22	12	14	10	7	7	4	3	2	6	262	2.21%
2005	49	29	27	56	28	18	10	11	8	5	5	3	2	6	258	2.39%
2006	46	39	23	22	45	22	14	8	9	6	4	4	3	6	252	2.52%
2007	57	37	32	19	18	35	18	11	6	7	5	3	3	7	258	2.71%

Table 1A.25. Estimates of age-2 pollock recruitment (in millions) based on reference model.

Year	Index at age 2	Year	Index at age 2
1978	66.7	2001	67.8
1979	88.1	2002	108.0
1980	301.6	2003	42.5
1981	68.5	2004	36.1
1982	44.6	2005	49.1
1983	78.2	2006	46.3
1984	77.7	2007	57.2
1985	78.4	2008	62.8
1986	71.7	Ave 90-06	54.5
1987	55.4	Med 90-06	51.3
1988	85.3		
1989	77.9		
1990	69.5		
1991	134.4		
1992	65.5		
1993	51.3		
1994	56.6		
1995	58.0		
1996	41.9		
1997	49.8		
1998	54.4		
1999	36.9		
2000	53.4		

Table 1A.26 Estimates of 2005 pollock fishery, survey, and projected fishery selectivity-at-age for Model 2B.

	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
M2B Fishery	0.025	0.061	0.154	0.374	0.707	0.810	0.808	0.858	1.002	1.223	1.644	2.111	2.111	2.111
Projected*	0.009	0.121	0.699	1.062	1.582	1.711	1.668	1.474	1.275	1.08	1.08	1.08	1.08	1.08
M2B Survey	0.062	0.181	0.409	0.583	0.689	0.758	0.812	0.861	0.972	1.167	1.335	1.385	1.385	1.385

* From the 2005 EBS pollock stock assessment (Ianelli et al. 2006).

Table 1A.27. Projections of Model 2B (with adjusted selectivity) female spawning biomass (in thousands of t), *F*, and catch (in thousands of t) for NRA pollock for the 8 scenarios. Fishing mortality rates given are based on the *average* fishing mortality over all ages.

Sp.Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2007	86.57	86.57	86.57	86.57	86.57	86.57	86.57	86.57
2008	82.25	82.25	84.00	85.24	85.80	81.40	82.25	83.48
2009	67.51	67.51	76.80	84.15	87.65	63.46	67.51	73.62
2010	60.19	60.19	73.72	85.53	91.50	54.80	59.65	67.43
2011	56.97	56.97	73.03	88.27	96.38	51.15	54.12	63.83
2012	55.54	55.54	73.22	91.32	101.38	49.84	51.44	61.63
2013	54.73	54.73	73.54	94.14	106.04	49.17	50.01	60.16
2014	54.08	54.08	73.68	96.44	110.04	48.65	49.08	58.97
2015	53.60	53.60	73.72	98.30	113.44	48.28	48.50	57.96
2016	53.29	53.29	73.76	99.83	116.31	48.07	48.18	57.10
2017	53.20	53.20	73.89	101.16	118.79	48.06	48.12	56.46
2018	53.21	53.21	74.06	102.29	120.90	48.13	48.16	55.99
2019	53.13	53.13	74.10	103.11	122.54	48.07	48.08	55.51
2020	52.87	52.87	73.93	103.55	123.68	47.82	47.83	54.89
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2007	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2008	0.20	0.20	0.10	0.03	0.00	0.24	0.20	0.13
2009	0.20	0.20	0.10	0.03	0.00	0.24	0.20	0.15
2010	0.20	0.20	0.10	0.03	0.00	0.24	0.24	0.16
2011	0.19	0.19	0.10	0.03	0.00	0.23	0.24	0.17
2012	0.19	0.19	0.10	0.03	0.00	0.22	0.23	0.18
2013	0.19	0.19	0.10	0.03	0.00	0.22	0.22	0.18
2014	0.19	0.19	0.10	0.03	0.00	0.22	0.22	0.18
2015	0.19	0.19	0.10	0.03	0.00	0.22	0.22	0.19
2016	0.19	0.19	0.10	0.03	0.00	0.22	0.22	0.19
2017	0.19	0.19	0.10	0.03	0.00	0.22	0.22	0.19
2018	0.19	0.19	0.10	0.03	0.00	0.22	0.22	0.20
2019	0.19	0.19	0.10	0.03	0.00	0.22	0.22	0.20
2020	0.19	0.19	0.10	0.03	0.00	0.22	0.22	0.20
Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2007	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40
2008	28.16	28.16	14.97	4.79	0.00	34.04	28.16	19.00
2009	22.67	22.67	13.40	4.62	0.00	26.06	22.67	19.00
2010	20.34	20.34	12.84	4.67	0.00	22.59	24.67	19.00
2011	19.45	19.45	12.89	4.86	0.00	20.70	22.33	19.00
2012	19.43	19.43	13.36	5.18	0.00	20.57	21.44	19.00
2013	19.45	19.45	13.69	5.42	0.00	20.59	21.01	19.00
2014	19.36	19.36	13.86	5.60	0.00	20.47	20.67	19.00
2015	19.18	19.18	13.82	5.66	0.00	20.30	20.39	19.00
2016	19.06	19.06	13.81	5.71	0.00	20.17	20.21	19.00
2017	19.02	19.02	13.83	5.77	0.00	20.16	20.18	19.00
2018	19.07	19.07	13.88	5.83	0.00	20.24	20.25	19.00
2019	19.03	19.03	13.89	5.86	0.00	20.21	20.21	19.00
2020	18.97	18.97	13.89	5.90	0.00	20.13	20.13	19.00

Table 1A.28. **Ecosystem effects on AI walleye pollock**

Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Zooplankton	Stomach contents, ichthyoplankton surveys	None	Unknown
Predator population trends			
Marine mammals	Fur seals declining, Steller sea lions increasing slightly	Possibly lower mortality on walleye pollock	No concern
Birds	Stable, some increasing some decreasing	May affect young-of-year mortality	Unknown
Fish (Pacific cod, arrowtooth flounder)	Pacific cod—decreasing, arrowtooth--stable	Possible decreases to walleye pollock mortality	No concern
Changes in habitat quality			
Temperature regime	The 2004 and 2006AI summer bottom temperature was near average. A warming since 2000 and 2002 were coldest and second coldest survey years respectively.	Warming from 2002 could affect apparent distribution.	Unknown

***The AI walleye pollock* effects on ecosystem**

Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Expected to be heavily monitored	Likely to be a minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Expected to be heavily monitored.	Bycatch levels should be low.	Unknown
HAPC biota (seapens/whips, corals, sponges, anemones)	Very low bycatch levels of seapens/whips, sponge and coral catches expected in the pelagic fishery	Bycatch levels and destruction of benthic habitat expected to be minor given the pelagic fishery.	No concern
Marine mammals and birds	Very minor direct-take expected	Likely to be very minor contribution to mortality	No concern
Sensitive non-target species	Expected to be heavily monitored	Unknown given that this fishery was closed between 1999 and 2005. The 2006 AICASS had 3% POP bycatch, the only significant bycatch. The 2005 fishery had a high bycatch of POP, but bycatch of other species was very low in fishery prior to 1999.	No concern
Other non-target species	Very little bycatch.	Unknown	No concern
Fishery concentration in space and time	Steller sea lion protection measures may concentrate fishery spatially to very small areas between 20 nm closures	Depending on concentration of pollock outside of critical habitat could possibly have an effect.	Possible concern
Fishery effects on amount of large size target fish	Depends on highly variable year-class strength	Natural fluctuation	Possible Concern
Fishery contribution to discards and offal production	Offal production—unknown. Fishery in 2005 expected to be conducted by CPs which may have fish meal production capabilities	Unknown	Unknown
Fishery effects on age-at-maturity and fecundity	Unknown	Unknown	Unknown

Figures

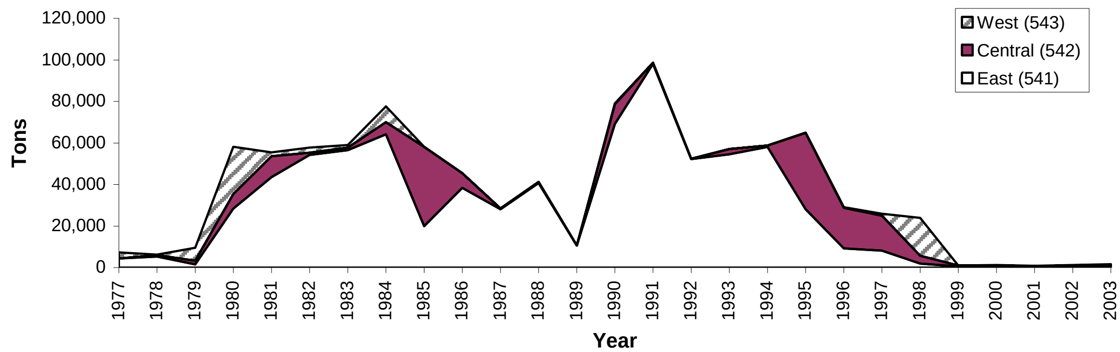


Figure 1A.1. Estimated pollock catch by sub-area of the Aleutian Islands Region, 1977-2003. Units in metric tons.

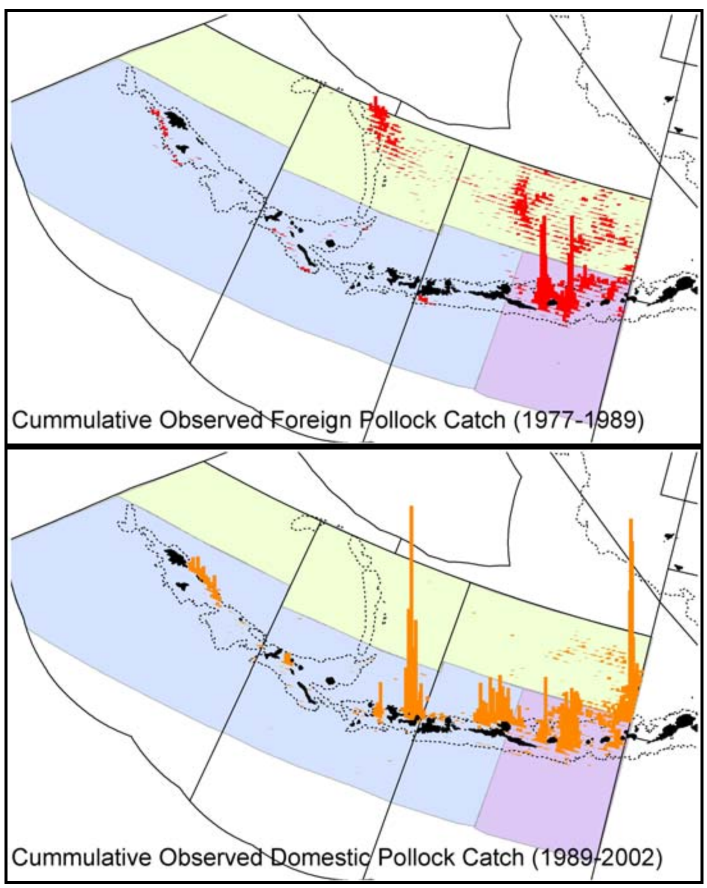


Figure 1A.2. Observed foreign and J.V. (1978-1989), and domestic (1989-2002) pollock catch in the Aleutian Islands Area summed over all years and 10 minute latitude and longitude blocks. Both maps use the same scale (maximum observed catch per 10 minute block: foreign and J.V. 8,000 t and Domestic 19,000 t). Catches of less than 1 t were excluded from cumulative totals.

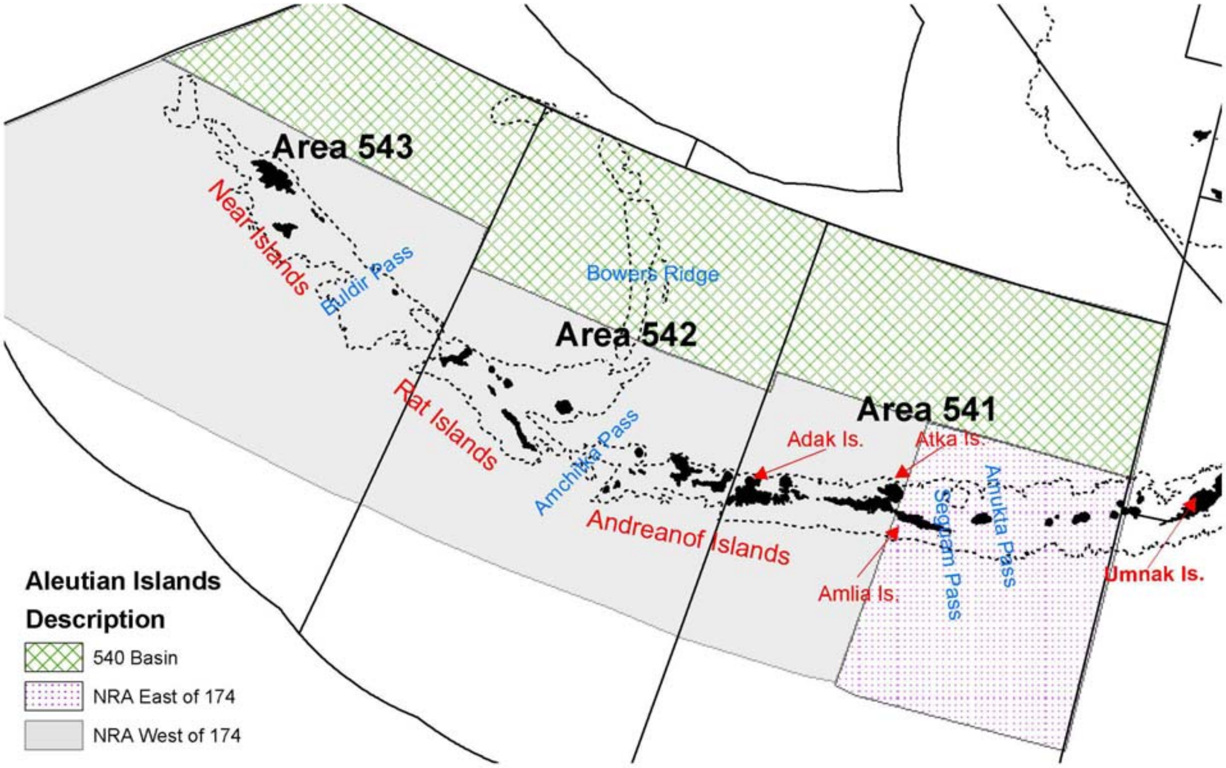


Figure 1A.3. Regions defined for consideration of alternative data partitions for Aleutian Islands Region pollock. The abbreviation "NRA" represents the Near, Rat, and Andreanof Island groups.

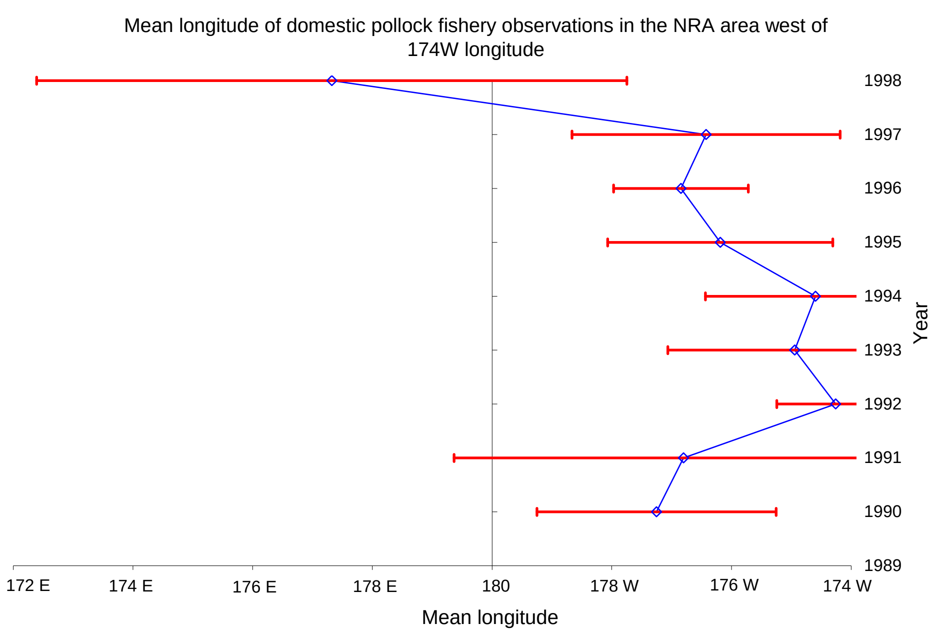


Figure 1A.4. Mean longitude of observed targeted domestic (1990-1998) pollock catch in the NRA west of 174 W longitude. Error bars indicate one standard deviation from the mean.

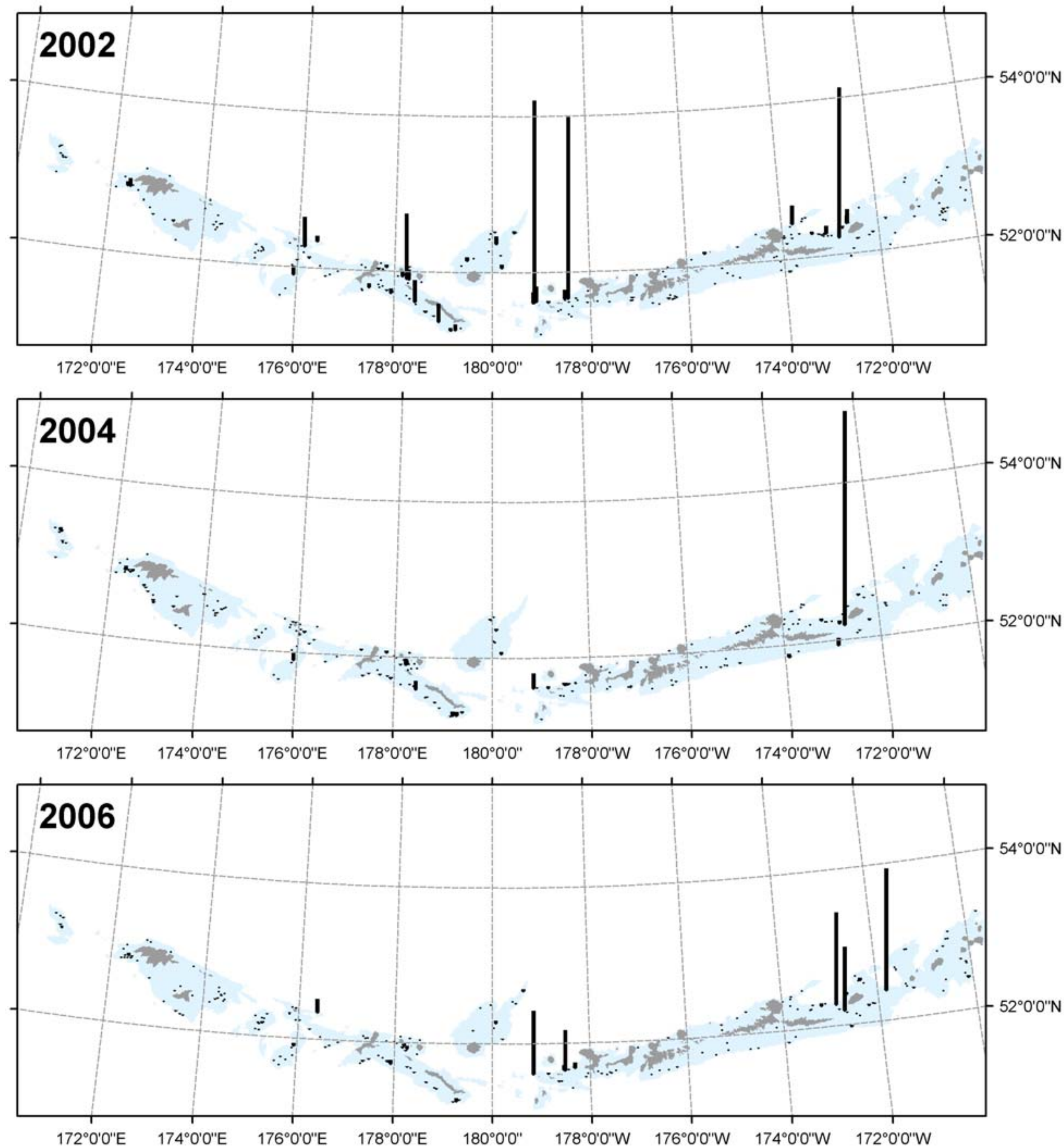


Figure 1A.5. Catch per unit effort (kg per m^3) for surveys of pollock in the Aleutian Islands Region, 2002-2006. The shaded area is the region surveyed.

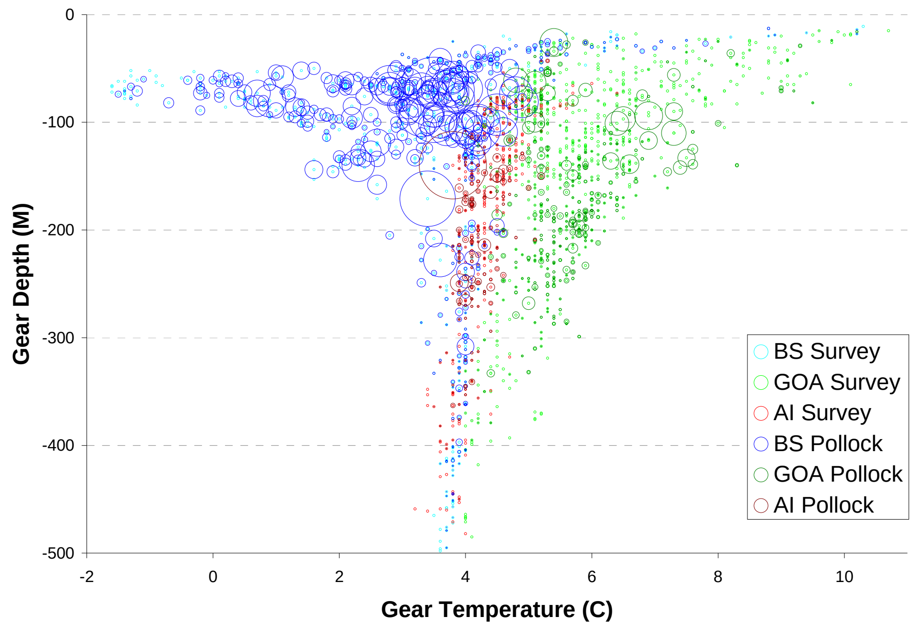


Figure 1A.6. Pollock CPUE (KG per m^3) by depth and temperature from the 2004 Aleutian Islands and Bering Sea and 2005 Gulf of Alaska bottom trawl surveys. Circle area is proportional to CPUE.

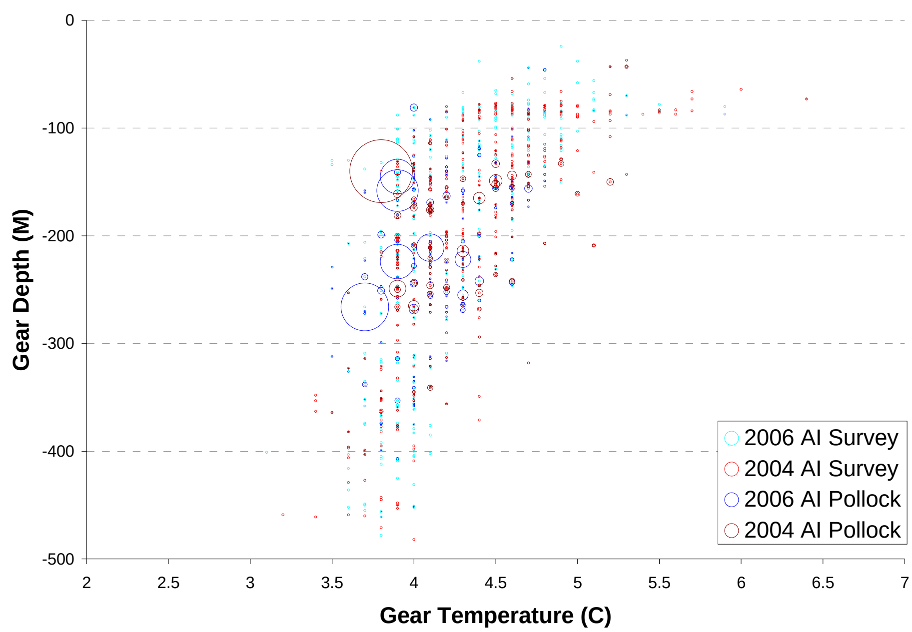


Figure 1A.7. Pollock CPUE (KG per m^3) by depth and temperature from the 2004 (red) and 2006 (blue) Aleutian Islands bottom trawl surveys. Circle area is proportion to CPUE.

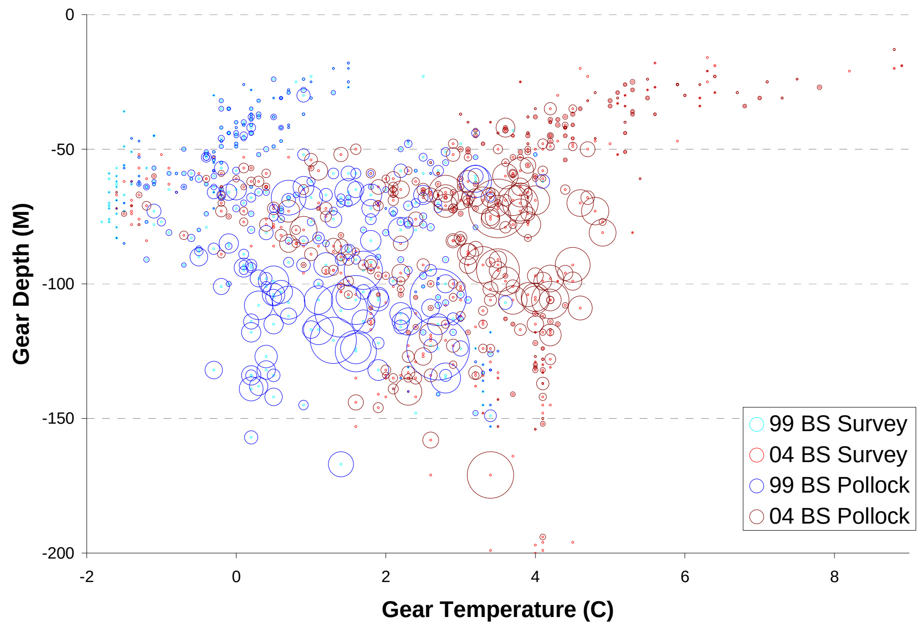


Figure 1A.8. Pollock CPUE (KG per m^3) by depth and temperature from the 1999 (blue) and 2004 (red) Bering Sea bottom trawl surveys. Circle area is proportional to CPUE.

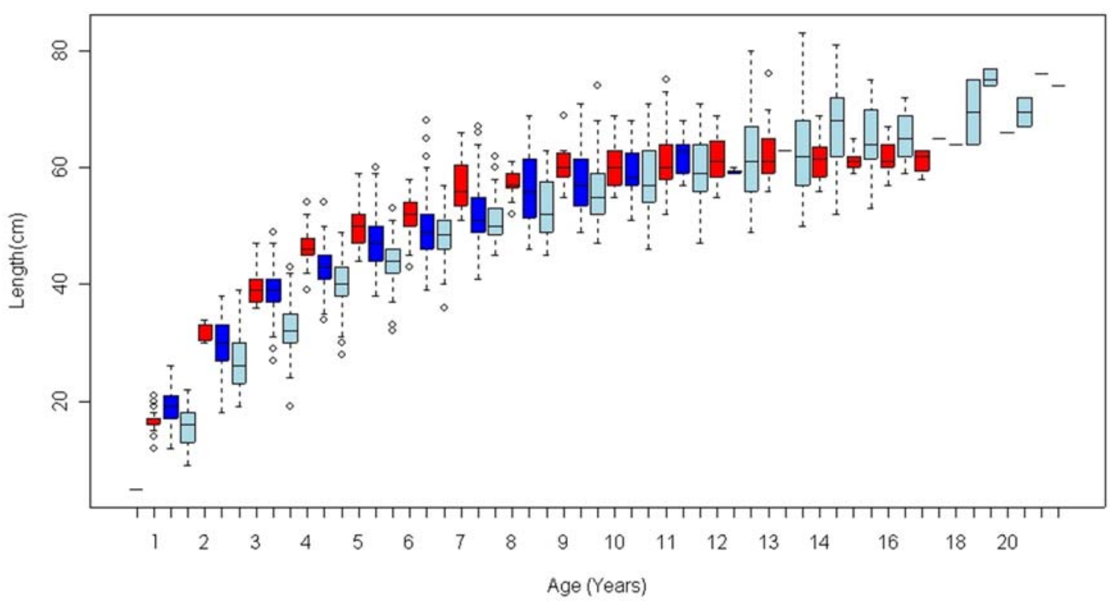


Figure 1A.9. Length at age for Aleutian Islands (red), Gulf of Alaska (blue), and Bering Sea (grey) pollock from the 2004 Aleutian Islands, 2004 Bering Sea, and 2005 Gulf of Alaska bottom trawl surveys.

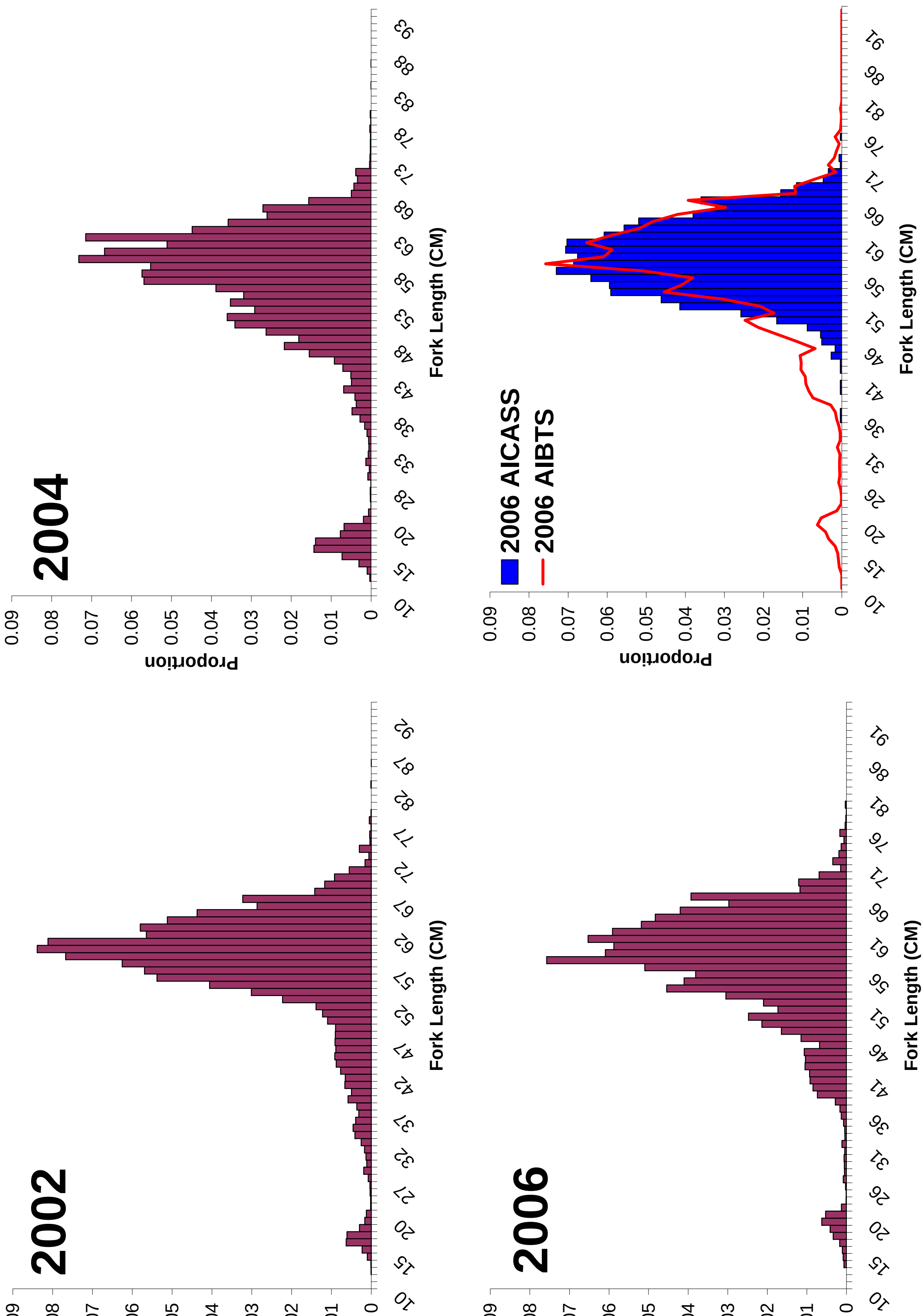


Figure 1A.10. Length distribution for 2002-2006 Aleutian Islands bottom trawl surveys and the 2006 Aleutian Islands cooperative acoustic survey study.

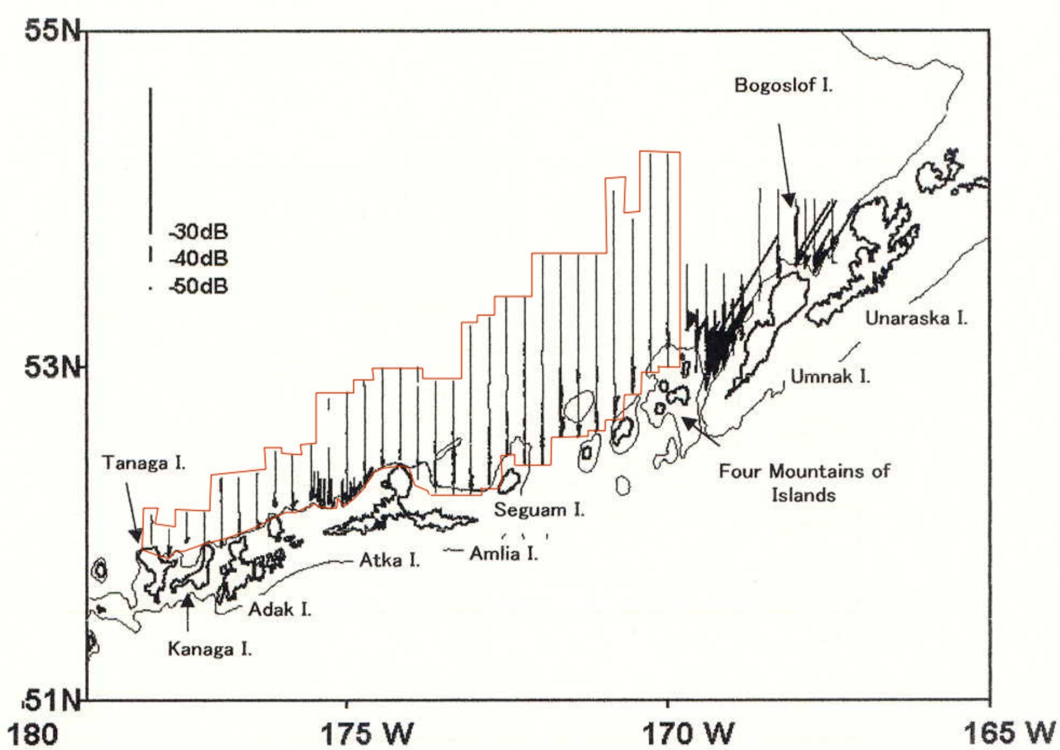


Figure 1A.11. R/V Kaiyo Maru 2002 echo integration-trawl survey (above) strata for leg2 and below observed S_A in both legs. Please note that in the bottom picture the encircled area is leg 2.

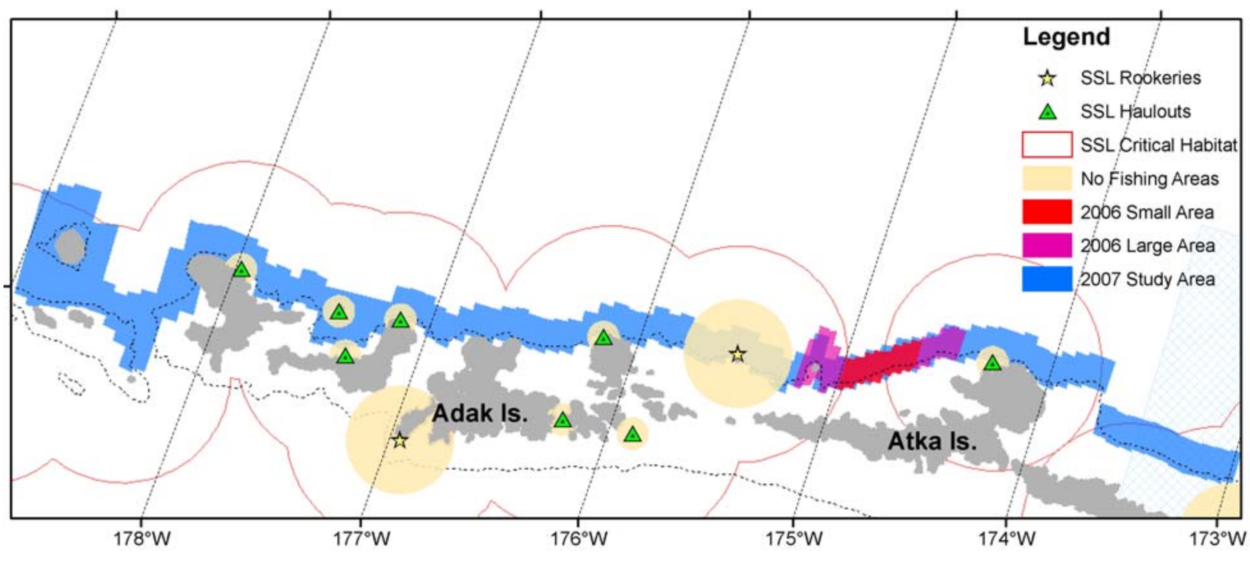


Figure 1A.12. 2006 and 2007 Aleutian Islands Cooperative Acoustic Survey Study sites within the central Aleutian Islands with pertinent Steller Sea lion areas.

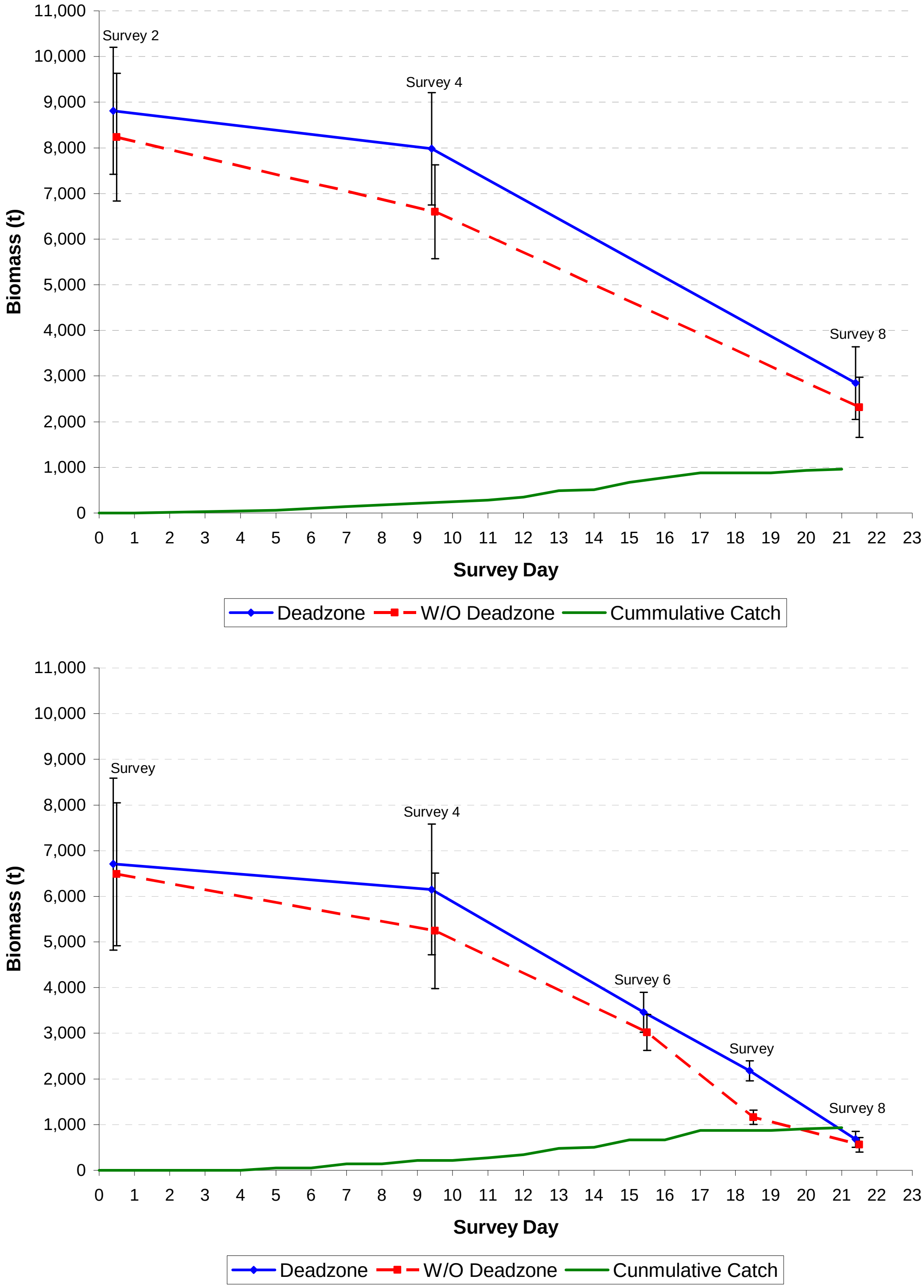


Figure 1A.13. Pollock abundance estimation and cumulative catch for large (top) and small (bottom) survey areas. Note error bars are $\pm 1.96 \times E_i \times B_i$. Method proposed by Kloser 1996 used to estimate biomass in the "Deadzone."

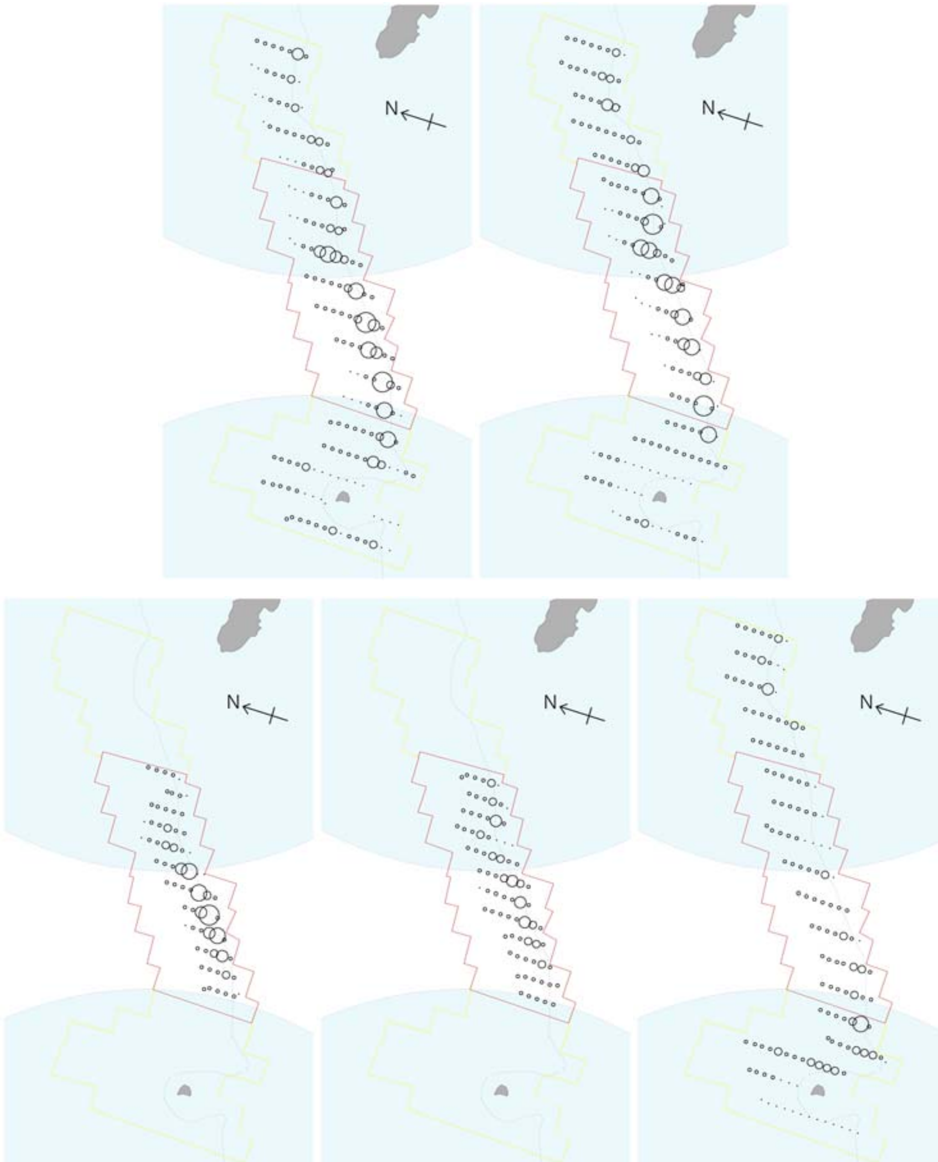


Figure 1A.14. 2006 AICASS distributions of pollock. Figures from left to right correspond to Surveys 2, 4, 6, 7, and 8.

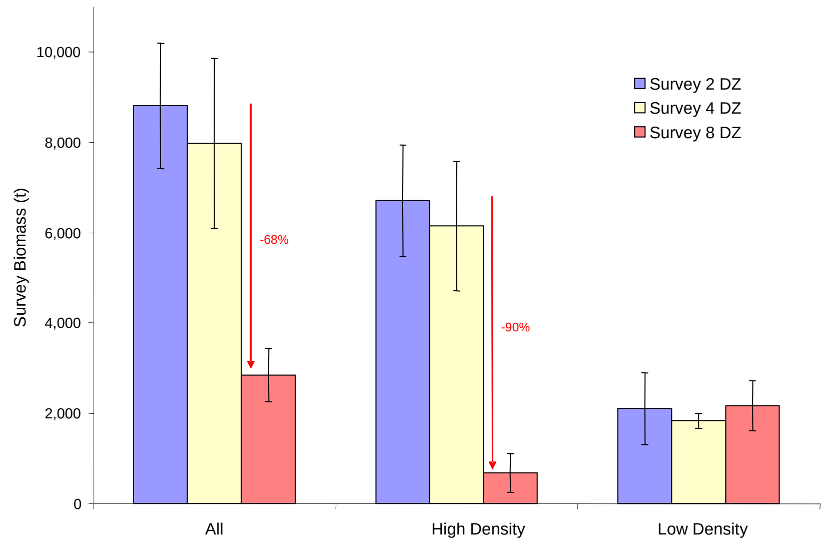
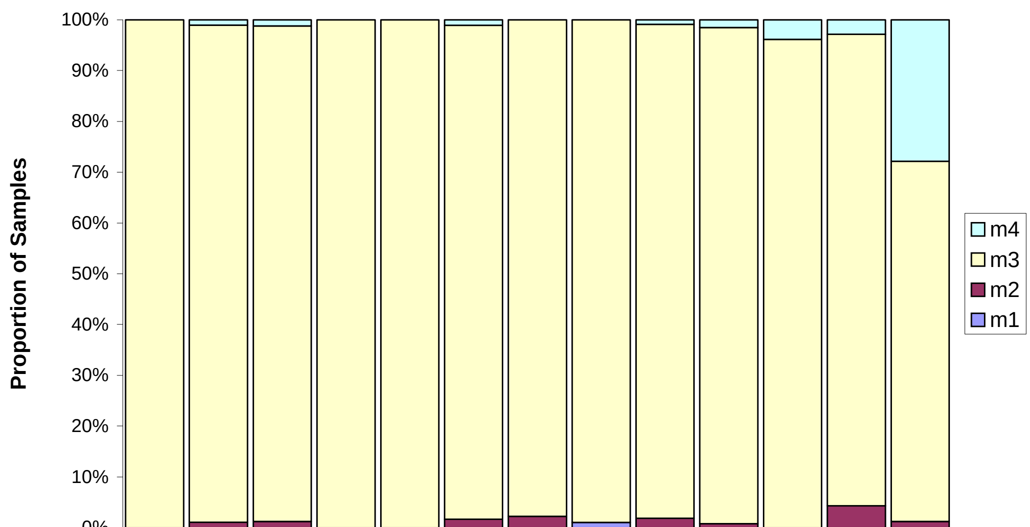


Figure 1A.15. Change in abundance for All, High Density, and Low Density areas. The High Density area corresponds with the small survey area while All corresponds with the large survey area, and Low Density corresponds with the large survey area outside of the small survey area. Arrows indicate a significant change in abundance from the first survey. Note: 935 t of the total 965 t caught during the 2006 AICASS were removed from the High Density area.



	0	1	4	6	8	10	12	13	14	16	18	19	20
m4	0	2	1	0	0	2	0	0	1	2	1	2	46
m3	5	183	82	147	112	176	310	98	105	128	25	65	117
m2	0	2	1	0	0	3	7	0	2	1	0	3	2
m1	0	0	0	0	0	0	0	1	0	0	0	0	0

Survey Day

Figure 1A.16. Female pollock maturity over the duration of the 2006 AICASS, m1 = immature, m2 = developing, m3 = pre-spawning, m4 = spawning, and m5 = spent. There were no spent fish observed during this survey.

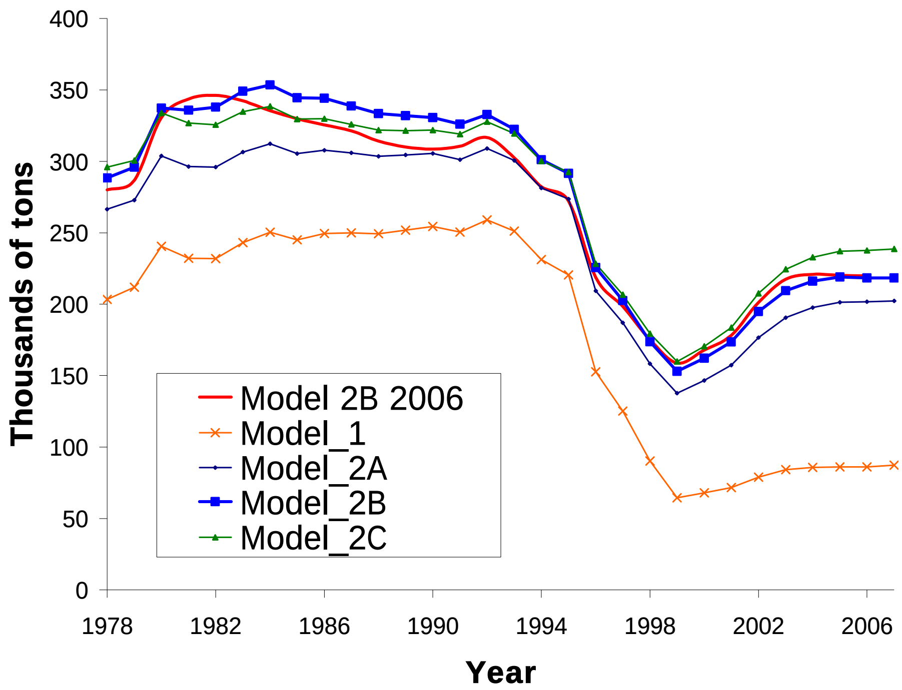
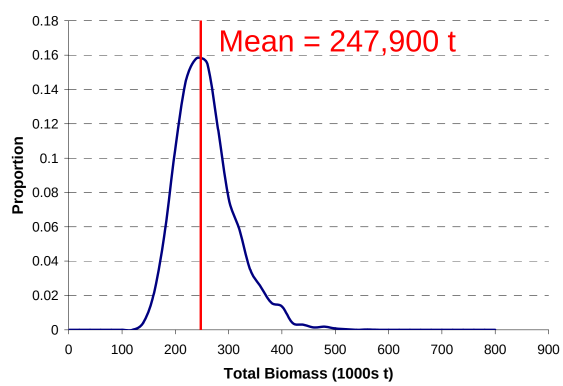


Figure 1A.17. Biomass trajectories under the four evaluated models compared with the 2006 reference model.



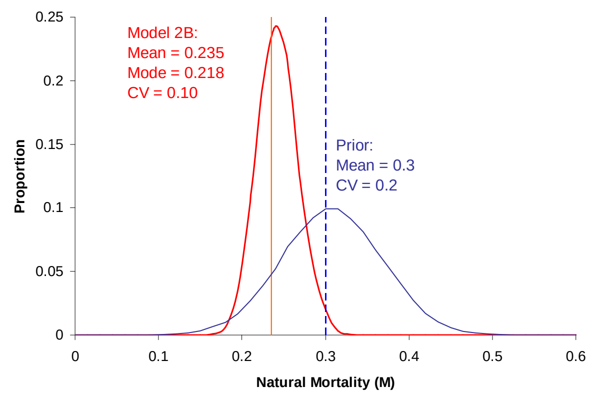


Figure 1A.18 2006 total biomass (right) and natural mortality (left) distributions from MCMC runs of Model 2B. Distributions were generated through 1,000,000 MCMC simulations sampled every 200 simulation.

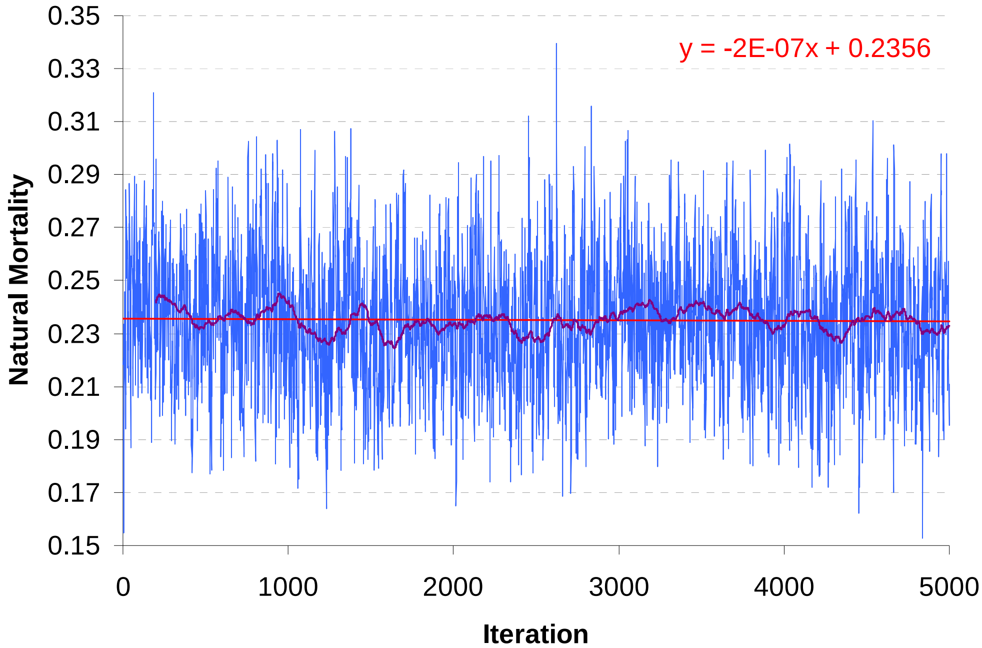


Figure 1A.19 Trace of natural mortality from MCMC simulations generated through 1,000,000 simulations sampled every 200th iteration for the two 6models. The purple line is a running mean for every 200th sampled iteration and the red line is a linear fit to the data showing a flat (slope of -9×10^{-7}) trajectory over 5000 iterations.

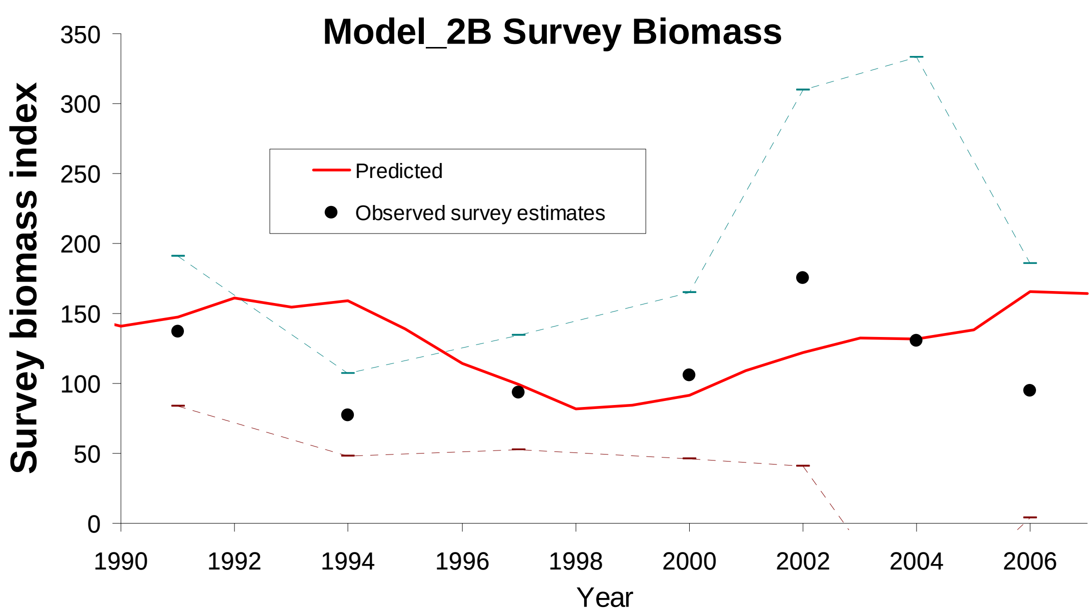


Figure 1A.20. Fit (solid line) to NMFS summer trawl survey (dots) for Model 2B. Dashed lines represent upper and lower confidence bounds of survey estimates.

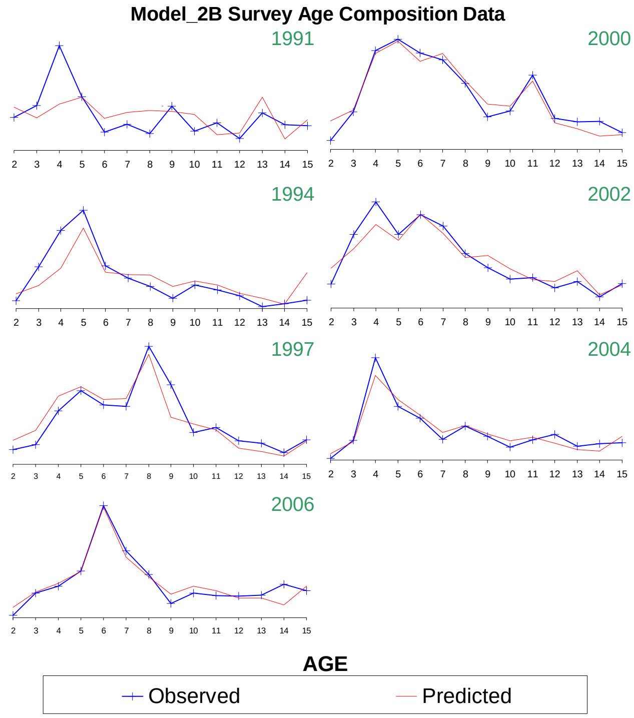


Figure 1A.21. Fits to NMFS summer trawl survey age composition data for Model 2B for Aleutian Islands pollock.

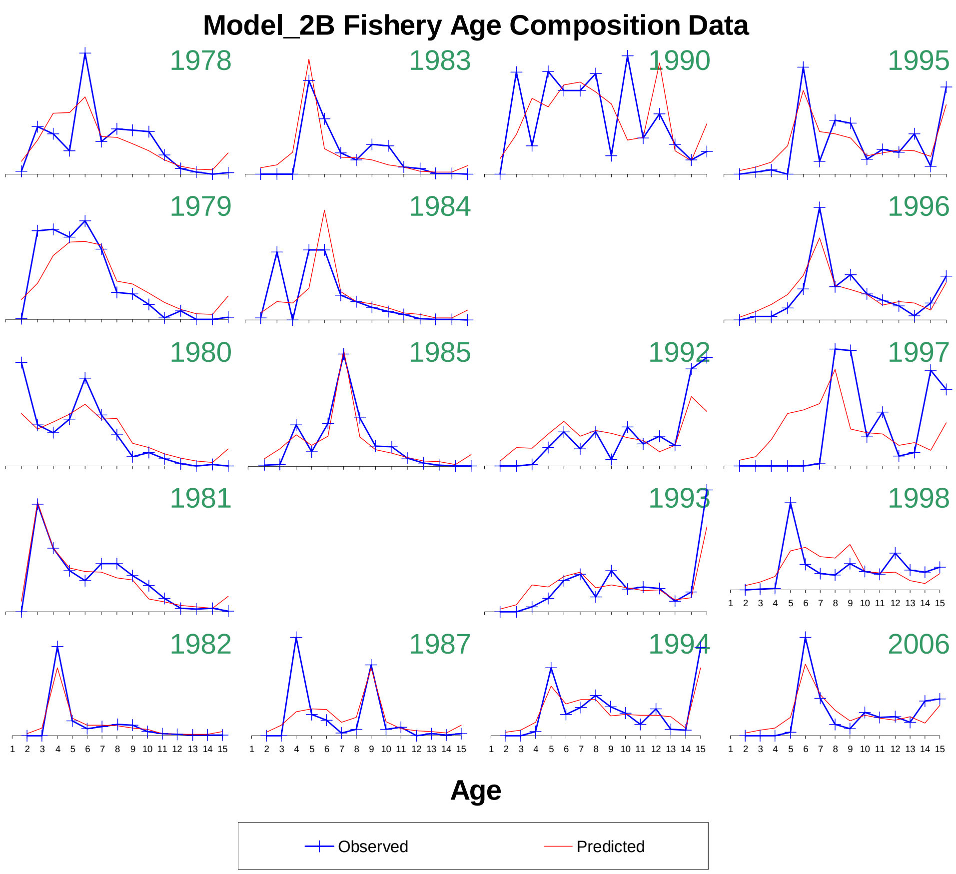


Figure 1A.22. Fit to fishery age composition data for Model 2B for Aleutian Islands (NRA) pollock.

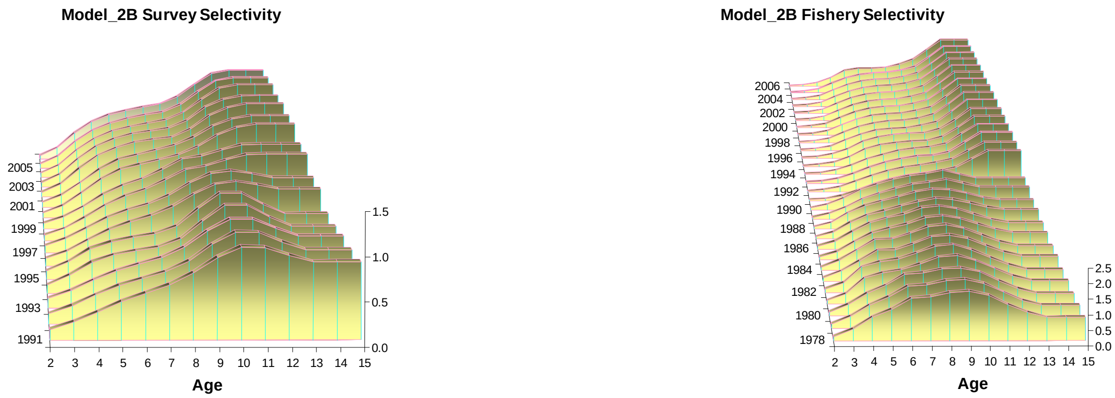


Figure 1A.23. Selectivity estimates for Aleutian Islands pollock for the bottom trawl survey (left) and the fishery (right) Model 2B.

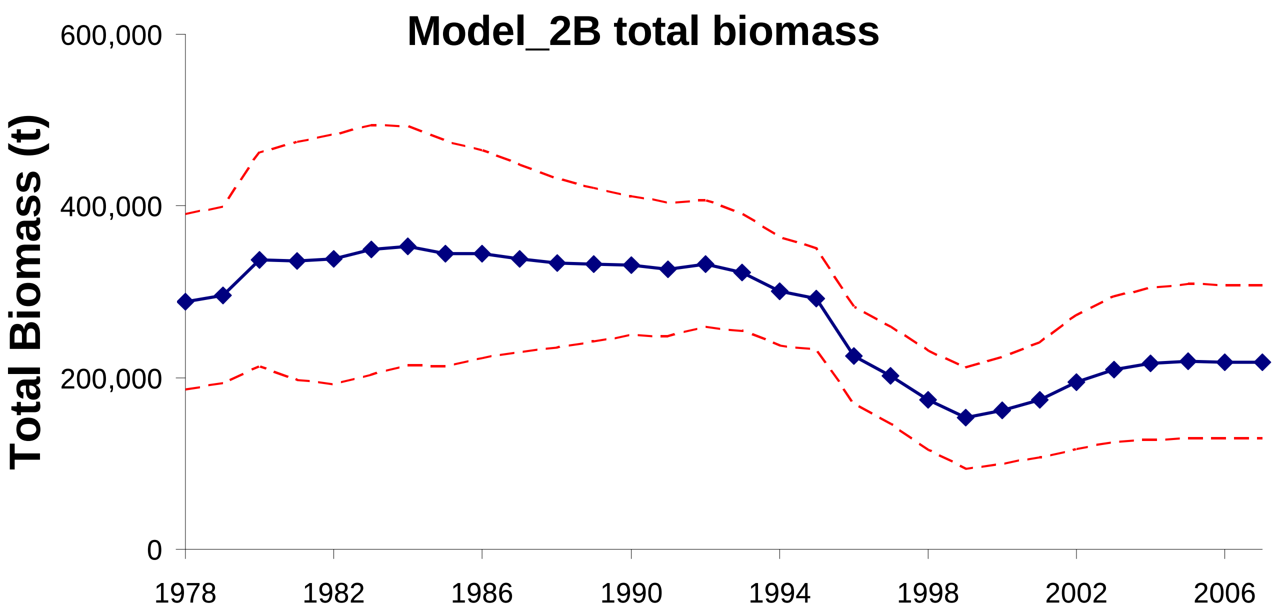


Figure 1A.24. Model 2B estimates of Aleutian Islands pollock age 2+ total biomass (in tons); dashed lines represent approximate upper and lower confidence bounds.

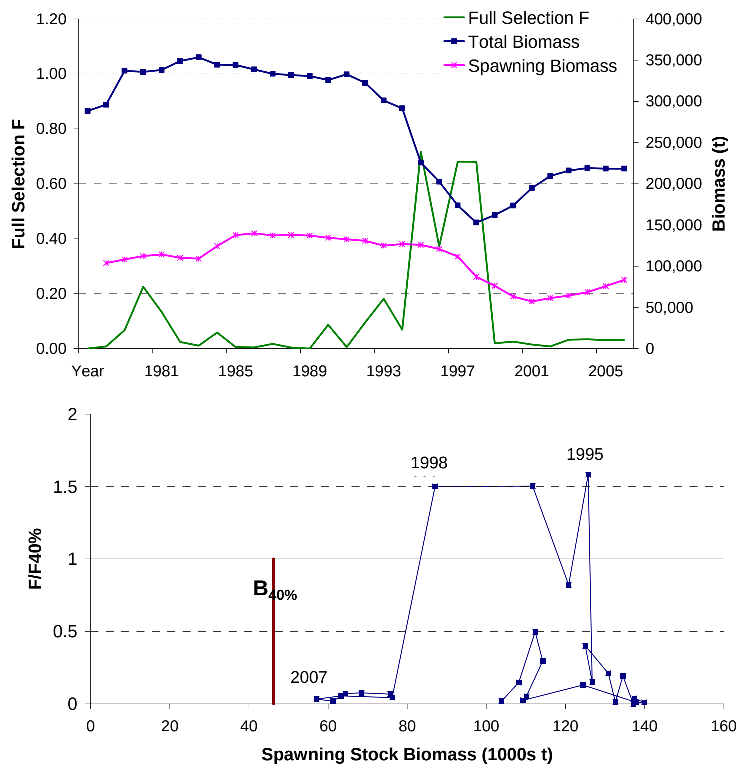


Figure 1A.25 Spawning biomass relative to $F_{40\%}$ values and fishing mortality rates for Model 2B AI pollock over time (top) and plotted jointly (bottom) for 1978-2006. Fishing mortality rates are based on the average over ages 2-15.

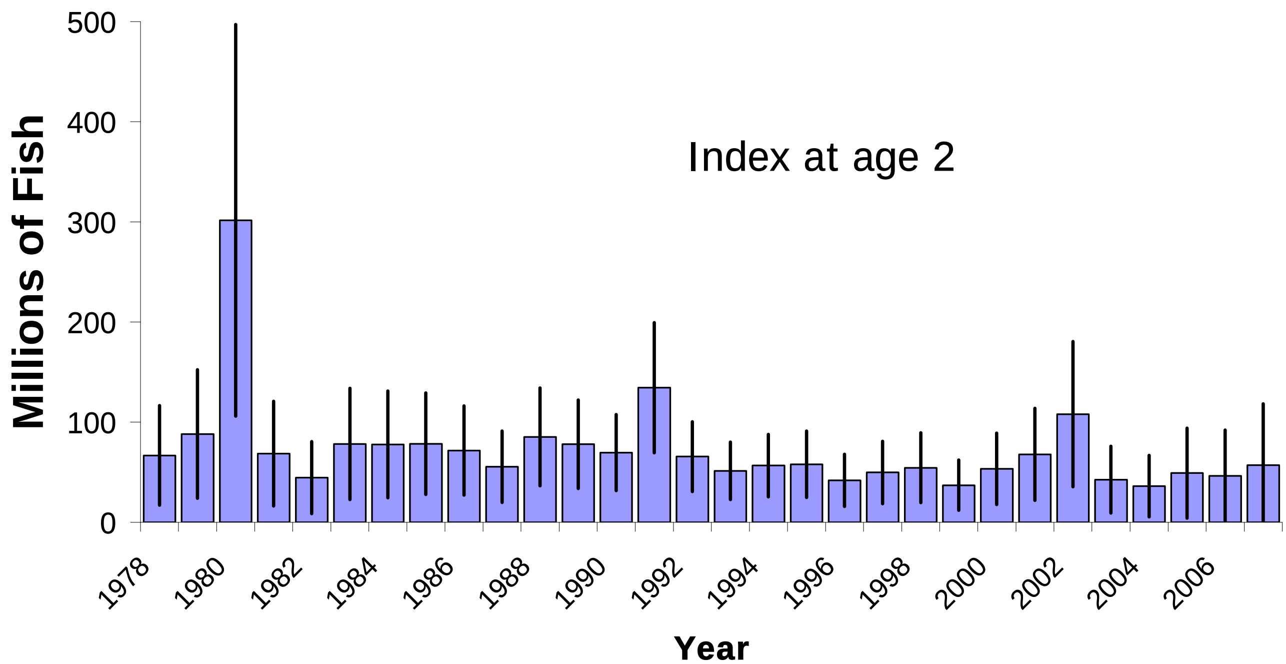


Figure 1A.26. Model 2B estimates of Aleutian Islands (NRA assessment area) pollock year-class estimates; vertical bars represent approximate upper and lower confidence bounds.

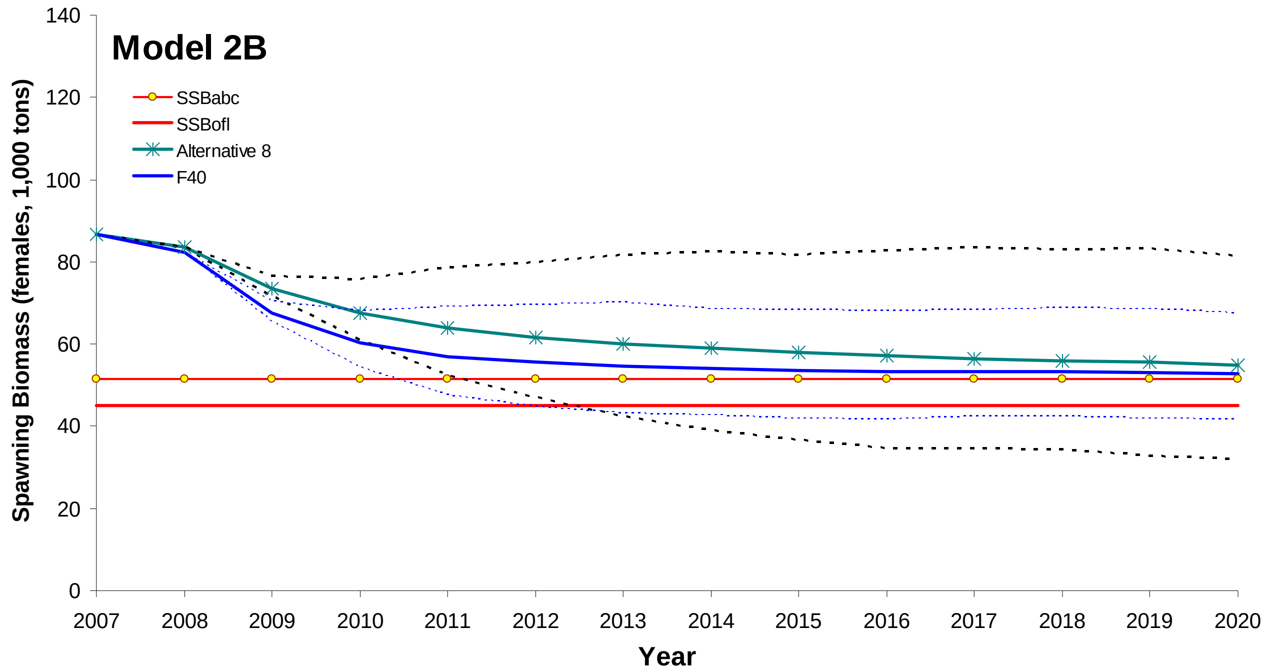


Figure 1A.27 Projected spawning biomass for $F_{40\%}$ and Alternative 8 ABC scenarios from Model 2B with adjusted selectivity-at-age.

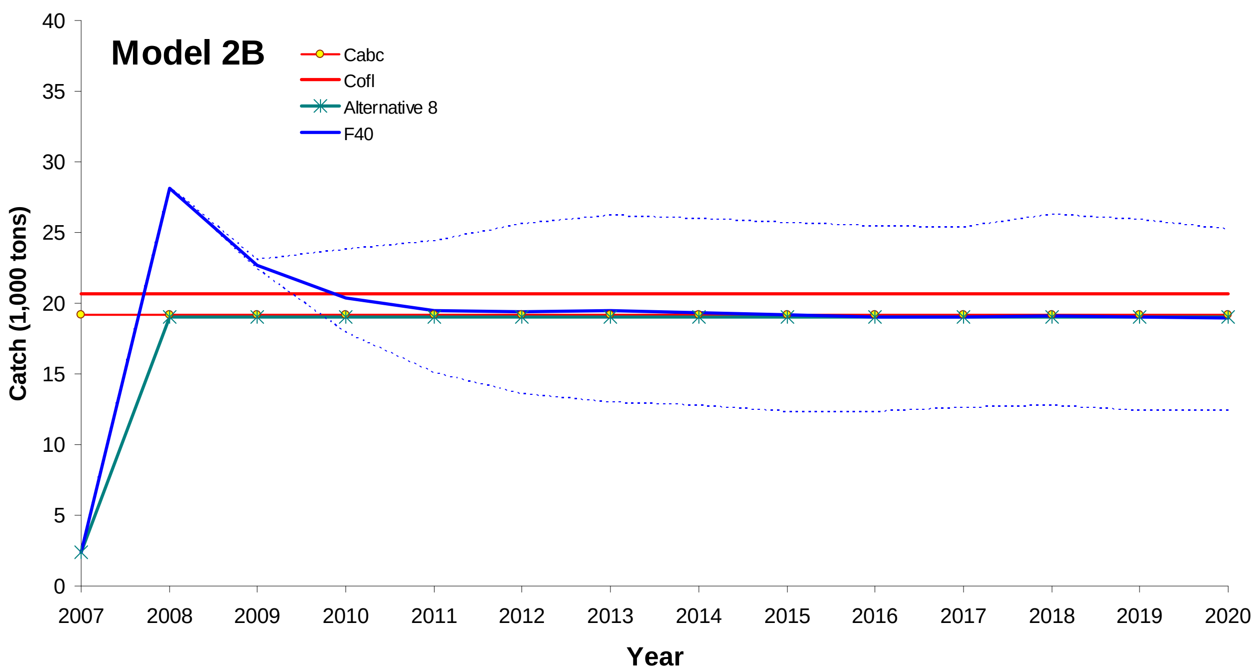


Figure 1A.28 Projected catch for $F_{40\%}$ and Alternative 8 ABC scenarios from Model 2B with adjusted selectivity-at-age.

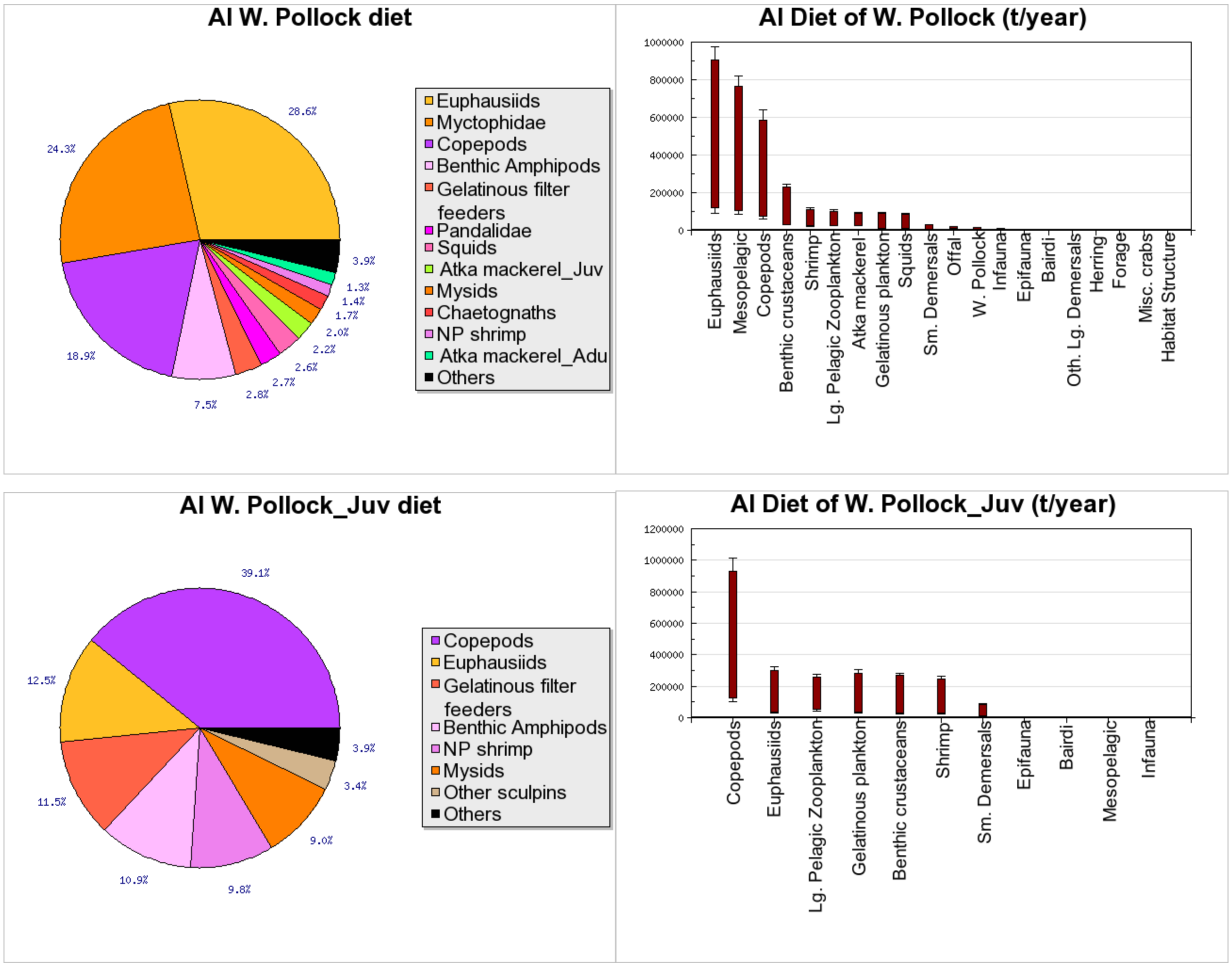


Figure 1A.29. Diet composition (left) and estimated consumption of prey (right) by AI adult (top) and juvenile (bottom) pollock. Diets are estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991-1994. See Appendix A for detailed methods.

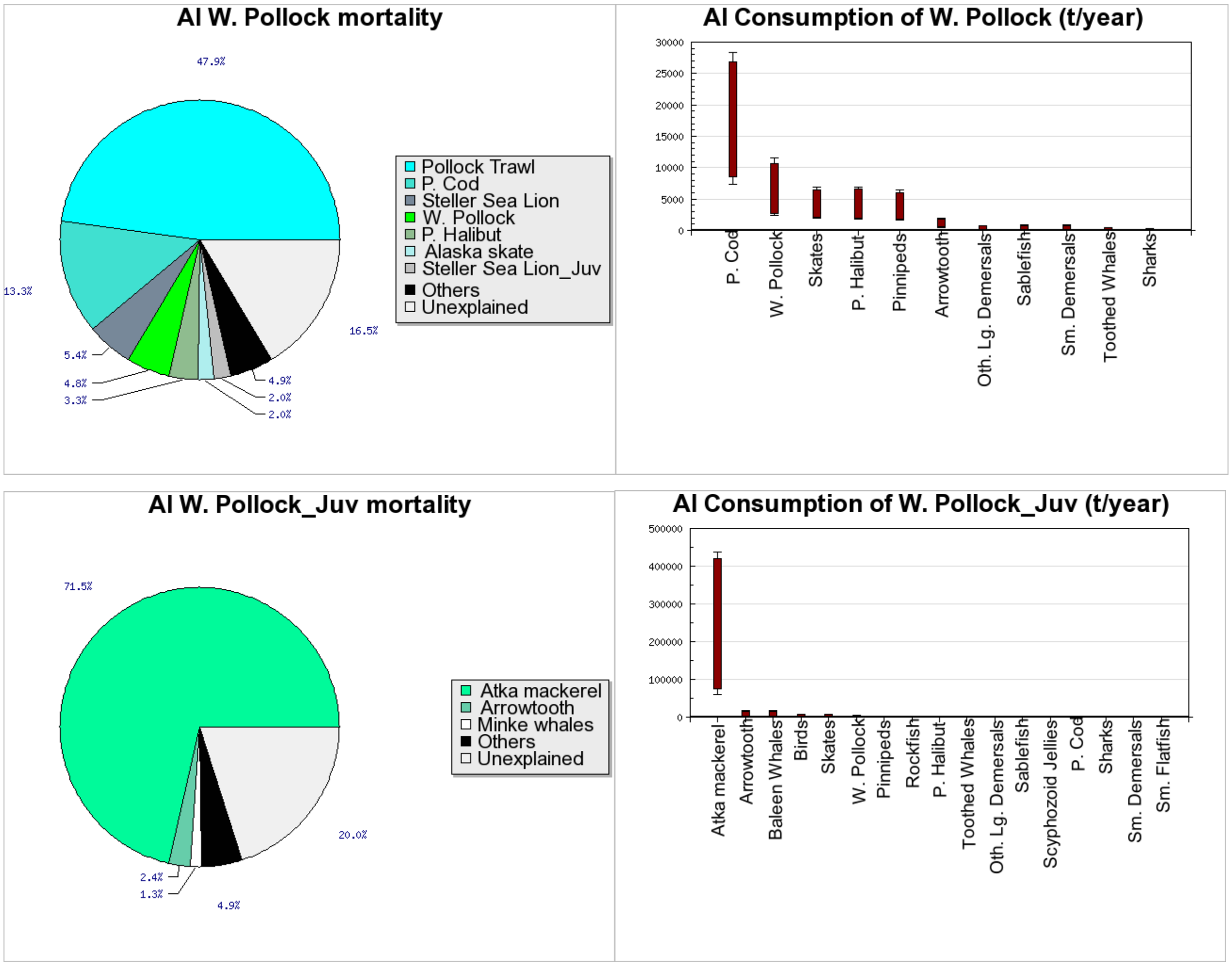


Figure 1A.30. Mortality sources (left) and estimated consumption by predators (right) of AI adult (top) and juvenile (bottom) pollock. Mortality sources reflect pollock predator diets estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991-1994, pollock predator consumption rates estimated from stock assessments and other studies, and catch of pollock by all fisheries in the same time periods. Annual consumption ranges incorporating uncertainty in food web model parameters were estimated by the Sense routines (Aydin et al in review). See Appendix A for detailed methods.

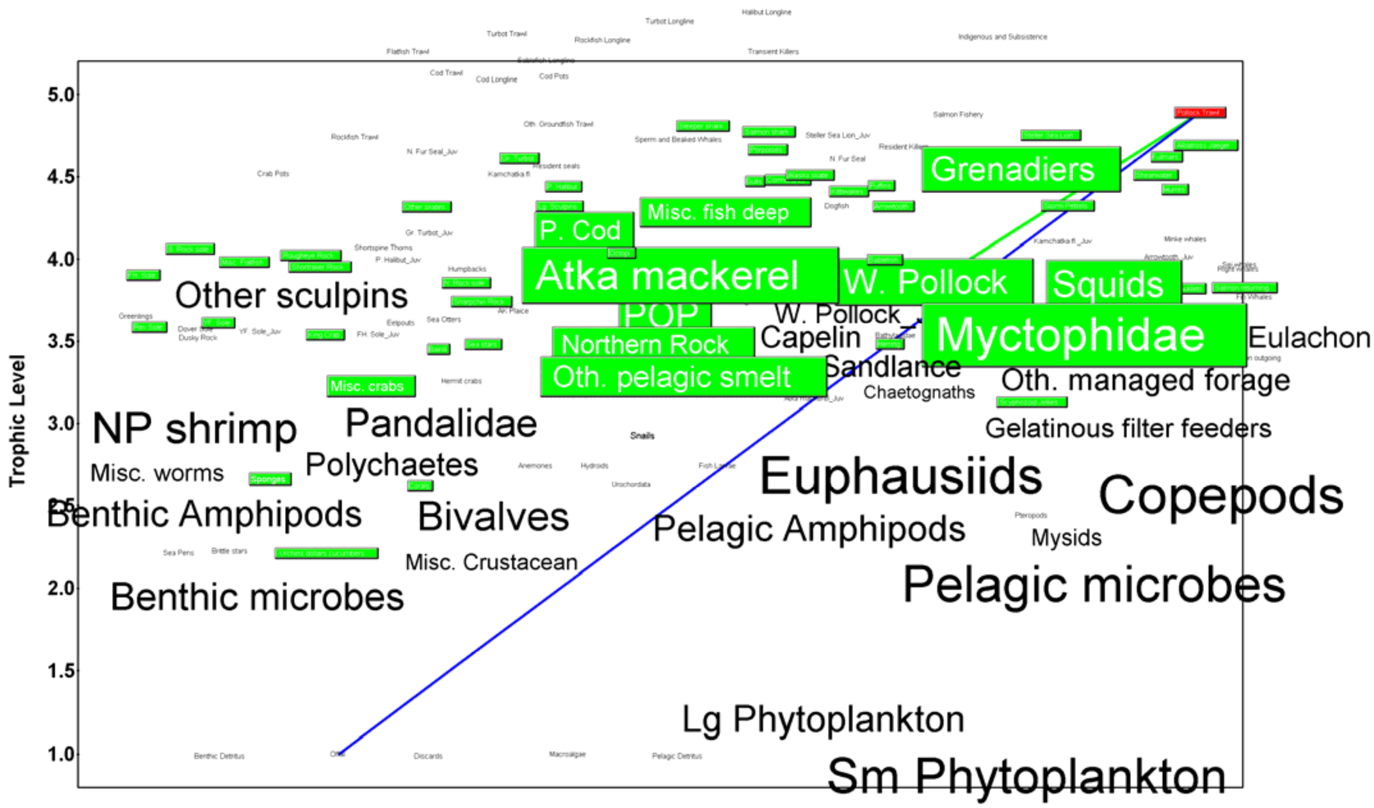


Figure 1A.31. The pollock trawl fishery in the AI food web. Species taken by the pollock fishery (in red) are highlighted in green, with the most significant flow to pollock indicated with a green line. Box size is proportional to biomass and lines between boxes represent the most significant energy flows. From Aydin et al (in review).

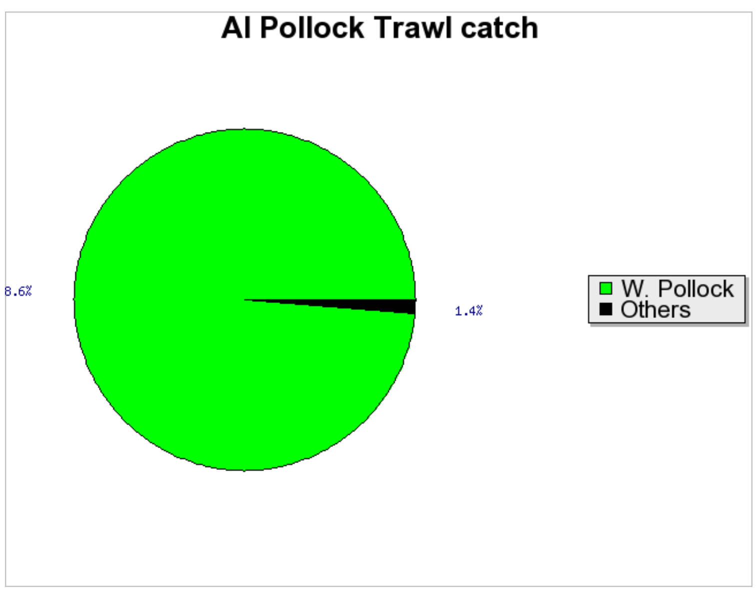


Figure 1A.32. Catch composition of the AI pollock trawl fishery during the early 1990's, as used in the food web model (Aydin et al Tech Memo).

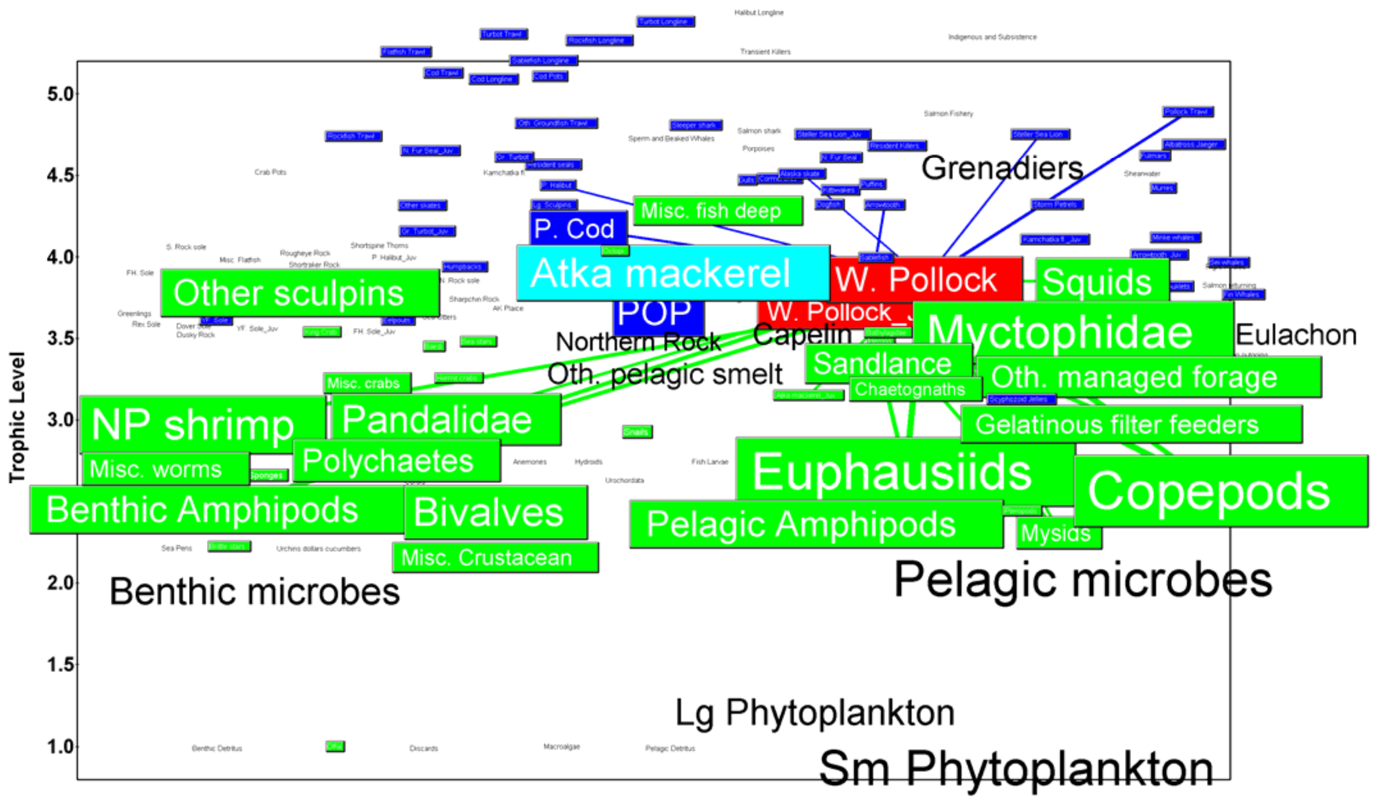


Figure 1A.33. Adult and juvenile pollock (highlighted in red) in the AI food web (Aydin et al Tech Memo). Predators of pollock are dark blue, prey of pollock are green, and species that are both predators and prey of pollock are light blue. Box size is proportional to biomass and lines between boxes represent the most significant energy flows.

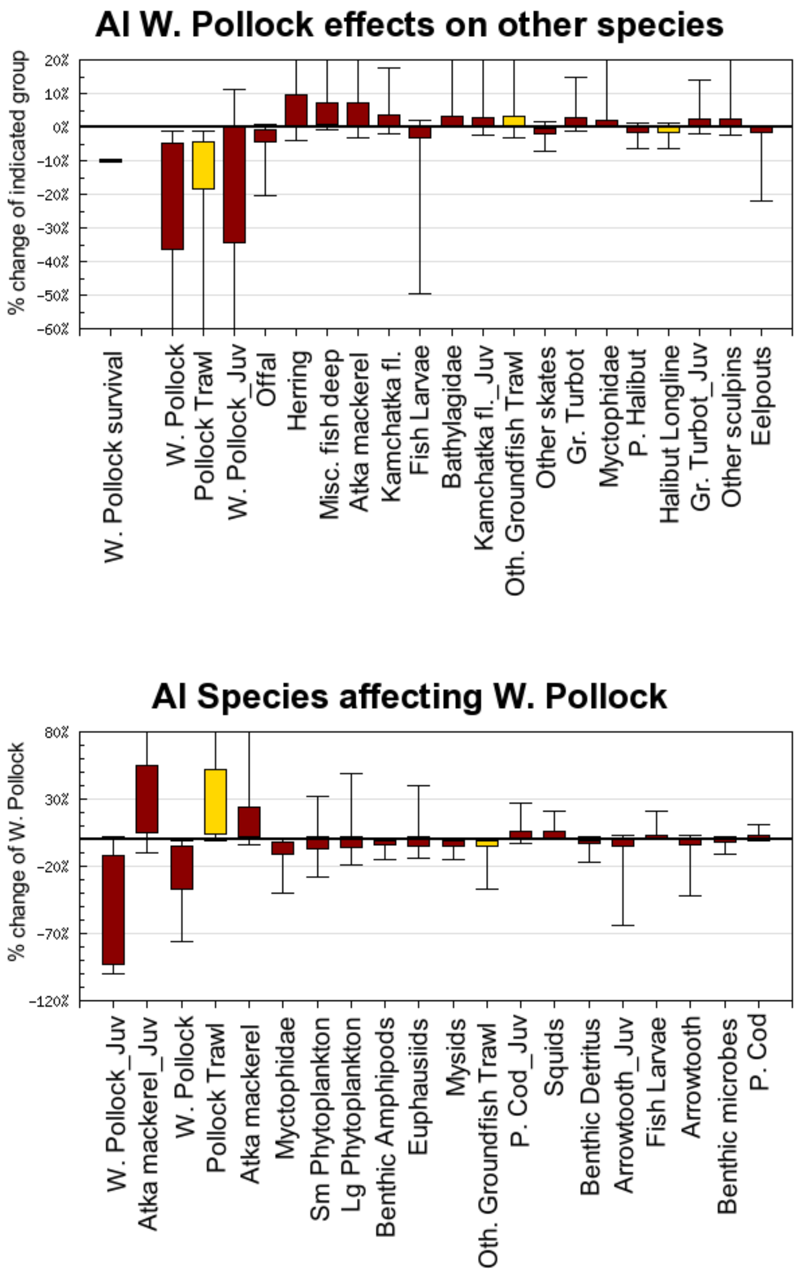


Figure 1A.34. (upper panel) Effect of changing pollock survival on fishery catch (yellow) and biomass of other species (dark red), from a simulation analysis where pollock survival was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. (lower panel) Effect of reducing fisheries catch (yellow) and other species survival (dark red) on pollock biomass, from a simulation analysis where survival of each X axis species group was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. In both panels, boxes show resulting percent change in the biomass of each species on the x axis after 30 years for 50% of feasible ecosystems, error bars show results for 95% of feasible ecosystems (see Aydin et al in review for detailed Sense methods).